2018 Forum on the Impact of Vehicle Technologies and Automation on Vulnerable Road Users and Driver Behavior and Performance: A Summary Report

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AAA Foundation for Traffic Safety

Title

2018 Forum on the Impact of Vehicle Technologies and Automation on Vulnerable Road Users and Driver Behavior and Performance: A Summary Report

(January 2019)

Foreword

Vehicle technologies continue to evolve at a rapid pace. As we continue to appraise how these changes will fundamentally affect future traffic safety and mobility, it is imperative that we strive toward a full understanding of driver behavior and performance when using these new systems. It is also critical that the impacts on vulnerable road users, both drivers and other road users, are fully explored.

This report summarizes presentations and discussion from a forum held in November 2018 at the University of Iowa in Iowa City. Stakeholders from academia, industry and government gathered to discuss and exchange information and ideas about the impact that emerging transportation technologies are having on vulnerable road users and on driver behavior and performance. This report should be of interest to researchers and practitioners who are involved with vehicle technologies and automation work.

C. Y. David Yang, Ph.D.

Executive Director
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About the Sponsor

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

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Abbreviated Terms

ADAS – Advanced Driver Assistance Systems

AAA – American Automobile Association

AEB – Automatic Emergency Braking

AV – Automated Vehicles

DOT – Department of Transportation

EDR – Electronic Data Recorder

FCW – Forward Collision Warning

FOT – Field Operational Test

HMI – Human-Machine Interface

HOV – High Occupancy Vehicle

LongROAD – Longitudinal Research on Aging Drivers

NADS – National Advanced Driving Simulator

NTSB – National Transportation Safety Board

NDS – Naturalistic Driving Study

ODD – Operational Design Domain

OEM – Original Equipment Manufacturer

V2P – Vehicle-to-Pedestrian

V2V – Vehicle-to-Vehicle

VRU – Vulnerable Road Users

Introduction

On Nov. 7 and 8, 2018, the AAA Foundation for Traffic Safety and the University of Iowa hosted a forum to discuss and identify future research needs on the impact of vehicle technologies and automation on vulnerable road users and on driver behavior and performance. This event followed from the inaugural forum, held in 2017, on similar issues related to emerging technologies. The 2018 event was attended by academics, automobile manufacturers and industry representatives, government agencies, advocacy groups and other research organizations (see Appendix A for a listing of participating organizations). The forum was co-sponsored by AAA Public Affairs, The Auto Club Group, the AAA Life Insurance Co., the SAFER-SIM University Transportation Center, the Transportation Research Board and the National Advanced Driving Simulator at the University of Iowa.

The main objectives of this forum were to: (a) gather representatives/experts from the research community, government and industry to discuss and identify research needs/direction on the impact of vehicle technologies and automation on vulnerable road users and on driver behavior and performance, (b) develop a summary report documenting research needs and share it with other stakeholders to improve coordination and encourage collaboration, and (c) encourage and promote cooperative efforts in addressing these pressing research needs.

On Day 1, two expert panels were convened to discuss a variety of topics related to vehicle technology, automation and their interaction with transportation system users. Each panel discussion was followed by an extended question-and-answer period. On Day 2, all attendees engaged in small breakout group discussions and presentations aimed at identifying the most pressing research needs. The panel presentations and discussions, breakout group exercise and outcomes are described in the sections below. The forum agenda can be found in Appendix B.

Day 1: Introductions and Panel Presentations

Drs. David Yang (AAA Foundation for Traffic Safety) and Daniel McGehee (University of Iowa, UI) opened the forum with welcoming remarks. President Bruce Harreld of the University of Iowa then provided a short keynote address, describing several innovations that originated at UI, the strong interdisciplinary focus on research, and the history and significance of the National Advanced Driving Simulator (NADS), which is celebrating its 20th anniversary. Mr. Brian Tefft of the AAA Foundation for Traffic Safety followed with a recap of the 2017 Forum on the Impact of Vehicle Technologies and Automation on Users and a discussion of some of the initiatives that came as a result of that forum. He also requested that other attendees share information with other delegates regarding their own efforts in this space.

Panel 1: Impacts on Vulnerable Road Users (Facilitated by Dr. Tara Kelley-Baker, AAA Foundation for Traffic Safety)

Mr. Kevin Dopart, U.S. Department of Transportation

Mr. Kevin Dopart provided an overview of several ongoing federal programs and initiatives related to automated vehicles. First, he described the recently released *Automated Vehicles 3.0* guidance document (https://www.transportation.gov/av/3). The report is organized according to six overarching principles: prioritization of safety, desire to remain technology-neutral, modernization of regulations, consistency in regulatory and operational environment, a proactive approach, and the protection and enhancement of freedoms of Americans.

Mr. Dopart further described U.S. DOT's role in ongoing automation research. One project related to the travel patterns of American adults with disabilities — an important issue related to accessibility and universal design (see Figure 1). Other programs involved an impact assessment of automated vehicles (AV), conducted at different levels (i.e., spatial resolution; e.g., individual, street, region, nation) and time frames. Mr. Dopart provided an overview of the Consolidated Appropriations Act, 2018, which funds highly-automated-vehicle research and development (https://www.congress.gov/bill/115th-congress/house-bill/1625). Lastly, he provided an overview of the Discussion Guide for Automated and Connected Vehicles, Pedestrians, and Bicyclists (http://www.pedbikeinfo.org/pdf/PBIC_AV.pdf), highlighting the important aspects of communication and intent for AV safety. For these, he noted the importance of identifying key information that must be shared by the AV with other road users, identifying the most effective means of this communication and providing research to inform human factors guidance regarding the communication of intent by AV.

Figure 1. Accessible Transportation Technologies Research Initiative (from Kevin Dopart, 2018, used with permission).

Dr. Joe Kearney, University of Iowa

Dr. Joe Kearney provided a comprehensive overview of simulation-based approaches and how they can be applied in the study of the impact of new technologies on pedestrians and bicyclists. He provided several video examples of studies from the Hank lab (https://psychology.uiowa.edu/hank-virtual-environments-lab) that examined an array of technologies, including vehicle-to-pedestrian (V2P communication), adaptive headlights, e-bikes and e-scooters, as well as AV.

In general, pedestrian and bicycle simulators can be implemented using different levels of fidelity, immersion and actors. Dr. Kearney also noted several inherent challenges and limitations that must be considered when applying simulation in this context. For example, in describing V2P collision warnings for pedestrians, it is very difficult to determine the appropriate thresholds for providing sufficient warning while also balancing the frequency of false alarms and misses. Dr. Kearney noted that it has proven very difficult to stop a pedestrian from attempting an unsafe crossing once he or she has begun to move (Figure 2).

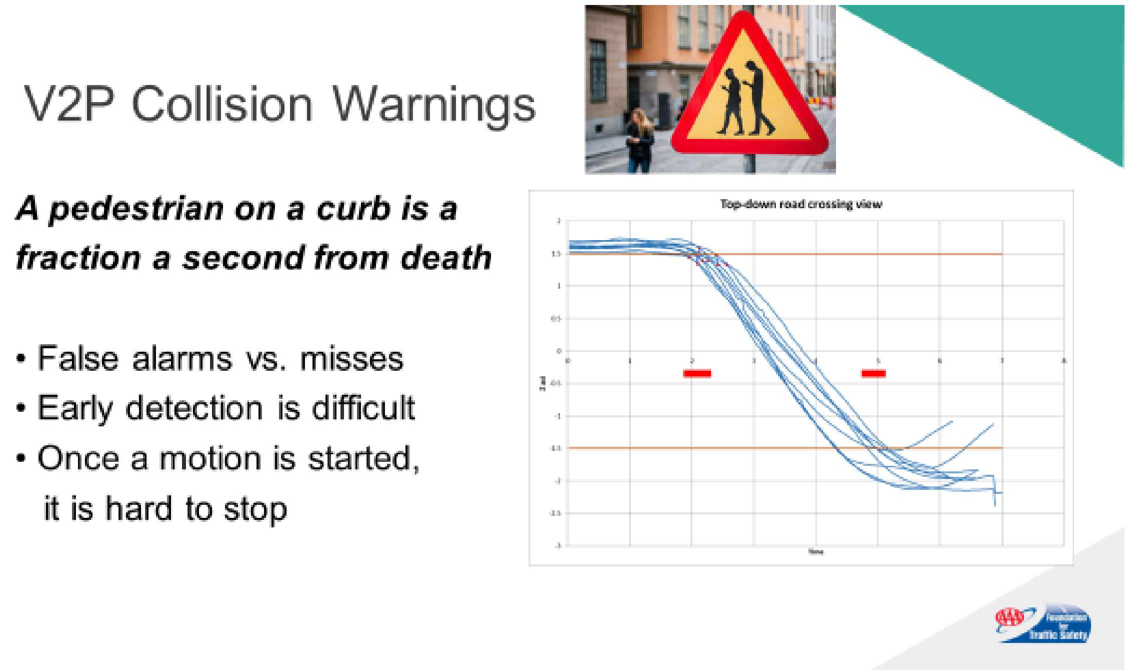


Figure 2. Inherent challenges with V2P collision warnings for pedestrians (from Joe Kearney, 2018, used with permission).

Dr. Donald Fisher, Volpe National Transportation Systems Center

Dr. Donald Fisher discussed the impact of AV on novice drivers, focusing on intended consequences, unintended consequences and countermeasures. He described current crash statistics and the most common crash configurations as a basis for focusing on the riskiest scenarios for teen drivers. That is, he mapped the riskiest scenarios to current or future crash avoidance technologies (Level 0 and higher); for example, rear-end crashes mapped to forward collision warning, automatic emergency braking and adaptive cruise control.

However, for all drivers — not just novice ones — there are risks of unintended consequences, including misuse, disuse and overgeneralization of the systems. Dr. Fisher discussed each in turn, including a detailed discussion of mode confusion, issues related to the operational design domain (ODD) and teen drivers' risk-taking tendencies. These consequences could be linked directly to driver training as well as consumer education. He noted how difficult and cumbersome existing information about system limitations (operational design domains) is, providing examples drawn from actual owners' manuals. He also noted that while the problem of overgeneralization (e.g., generalizing the functionality of the crash avoidance system of one vehicle to a different vehicle with a less capable crash avoidance system or no crash avoidance system) is not unique to young novice drivers, they may be more vulnerable to overgeneralization due to their lack of driving experience. Given the challenges that novice drivers already face in terms of skill development, they could be considered the perfect storm for the sorts of unintended consequences described earlier. Dr. Fisher speculated on the potential role of in-vehicle attention monitoring, augmented reality, other active constraints (speed limiters) and training for this vulnerable driver population.

Dr. David Eby, University of Michigan

Dr. David Eby discussed the intersection of new advanced technologies and older drivers. He underscored the importance of this group of road users given national and global demographic trends. Within this population, driving and mobility are tightly linked to overall quality of life. Technology is considered to have great potential to extend the safe driving lifetime of this population. That said, data from the ongoing AAA Longitudinal Research on Aging Drivers (LongROAD) project (https://aaafoundation.org/) show that in spite of this great potential, the current prevalence of technologies in vehicles owned by older adults is only moderate and actual use of the technologies within this group is only moderate as well. In spite of this, drivers believe the technologies make them safer.

Dr. Eby elaborated on some of the challenges that advanced levels of automation (Level 3+) pose for this vulnerable driver group, including training/education, trust and availability. He also underscored some of the unique nondriving-specific challenges associated with meeting the transportation needs of older users, including transitioning to and from the vehicle, vehicle ingress/egress, and communication and feedback from the system to the driver (or passenger, in higher levels). Lastly, Dr. Eby discussed research needs focused on older drivers and advanced technologies, including older-driver understanding and acceptance of AV technology as well as their real-world use of these systems (see Figure 3).

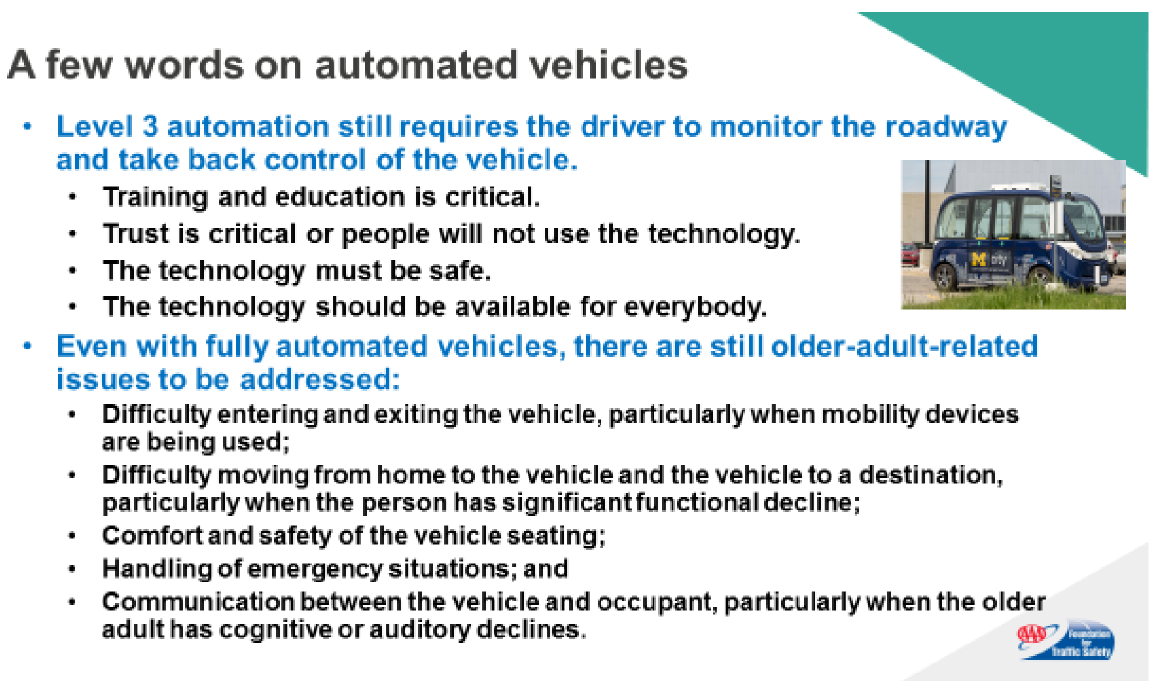


Figure 3. Challenges associated with higher levels of automation for older driving population (from David Eby, 2018, used with permission).

Due to travel disruptions, the fifth panelist, Dr. James Jenness from Westat, was unable to deliver his prepared remarks; however, was able to join the panel discussion in progress.

Panel 1 Discussion

After Dr. Kelley-Baker provided a brief synopsis of key themes in the panelists' presentations, the panelists responded to questions from attendees. Multiple questions centered on the issue of how systems should be designed to accommodate special populations (e.g., the young, inexperienced or elderly), and how or whether training for automation should be delivered. In response, panelists noted that systems designed to meet the needs of such special populations will likely work well for other users as well, reiterated the importance of training and of measures to maintain basic driving skills, and suggested that design guidelines that include monitoring driver state/situation awareness might be helpful. Other topics discussed included how highly automated vehicles could communicate with other road users (pedestrians, cyclists, human drivers of conventional vehicles), the point at which automation should be designed to override a driver's intent, techniques to study interactions between AV and vulnerable road users, and how highly automated vehicles will interact with emergent and yet unforeseen types of road users (e.g., electric scooters).

Panel 2: Impacts on Driver Behavior and Performance (Facilitated by Dr. William Horrey, AAA Foundation for Traffic Safety)

Dr. Tom Dingus, Virginia Tech Transportation Institute

Dr. Tom Dingus led off his presentation with a discussion of the likely timetable for the rollout and penetration of AV in the current vehicle fleet. The aim was to provide more context for a so-called “worry timeline” in guiding research priorities. For example, many of the large-scale societal impacts of AV might not manifest themselves for many years or decades. Dr. Dingus noted that AV will need to perform more safely than human drivers by a large multiple before they will be accepted widely, due to the nature of human risk perception, and also noted some less salient barriers to adoption of AV (e.g., prevalence of people who experience motion sickness when riding as a passenger). He also described several network level issues when considering AV (e.g., Figure 4): the likelihood of perpetual manual components in the system, difficulties for AV to predict highly variable and possible rule-breaking behaviors, potential for users taking advantage of system, socioeconomic status considerations and driver level issues — ignoring system alerts with increased exposure, engagement in other activities, etc.

Dr. Dingus also outlined some ongoing research efforts that are leveraging data from recent naturalistic driving studies (NDS) to try to better understand some of the behavioral and performance implications of AV and ADAS technology. In particular, this research is examining some of the real-world unintended consequences of ADAS in terms of driver secondary task engagement and driver drowsiness.

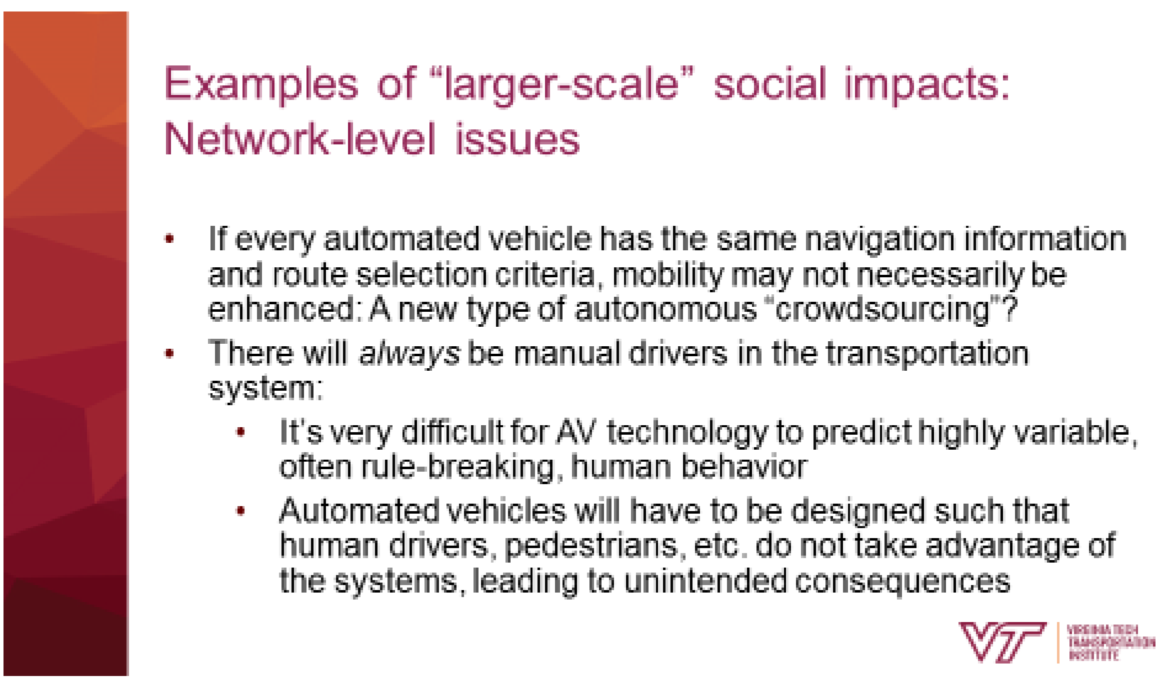


Figure 4. Large-scale social impacts of AV (from Tom Dingus, 2018, used with permission).

Dr. Kristin Poland, National Transportation Safety Board

Dr. Kristin Poland provided an overview and update on five recent and/or ongoing crash investigations of AV being conducted by the NTSB. The crashes were in Williston, Florida (2015 Tesla Model S); Las Vegas, Nevada (2017 Navya Arma shuttle); Culver City, California (2014 Tesla Model S); Tempe, Arizona (Uber test vehicle with 2017 Volvo XC90 platform); and Mountain View, California (2017 Tesla Model X). These were selected for discussion because they represented a variety of severities and scenarios (e.g., crossing traffic, expectations of other drivers, road users, pedestrian involvement, HOV lane and emergency vehicles, left-hand exit).

Based on these investigations, Dr. Poland underscored the importance of a clear expression and understanding of the vehicle's operational design domain (ODD), monitoring of driver behavior, electronic data recorder (EDR) for AV, well-defined safety metrics and exposure data, and vehicle-to-vehicle (V2V) communication.

Dr. Linda Angell, Touchstone Evaluations

Dr. Linda Angell discussed the impact of AV technology on driver behavior and performance in the context of some ongoing field operational test (FOT) and naturalistic driving study (NDS) work, under the Advanced Vehicle Technology (AVT) Consortium, hosted by MIT. She highlighted the overall approach to and current status of data collection and pointed out several of the technical challenges associated with these on-road studies. Over the course of the project, they have amassed thousands of control transfers, which are now being examined.

Dr. Angell also showcased some examples of driver (mis)understanding and expectations as well as issues related to "nuisance" alerts. These illustrated the importance of drivers' mental models of AV technology. The results from the ongoing study also provided some compelling evidence of confusion over which AV systems the drivers' vehicles actually had (Figure 5). Dr. Angell also reflected on some important research needs, including how to identify and suppress unneeded system alerts, how to build better understanding of AV systems (including how to effectively deliver this information to users), and how to address issues of automation complexity and transparency.

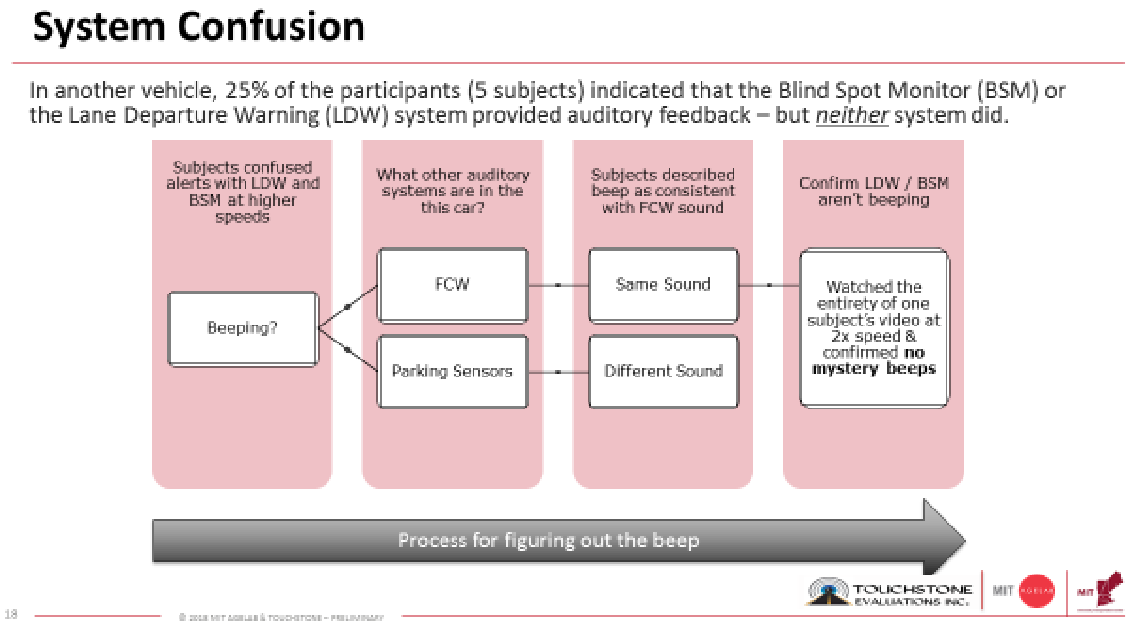


Figure 5. Example of system confusion in drivers of vehicles equipped with AV technology (from Linda Angell, 2018, used with permission).

Dr. Daniel McGehee, University of Iowa

Dr. Daniel McGehee provided a comprehensive overview of some recent work that examined the perceptions, understanding and experiences of owners of ADAS-equipped vehicles (https://aaafoundation.org/vehicle-owners-experiences-reactions-advanced-driver-assistance-systems/). In the survey study, researchers asked about drivers' awareness and understanding of technology prior to purchase, perceptions of the importance of the technology, experience with technology (e.g., did they experience AEB, FCW), degree of reliance on the technology and other behaviors while using the technology, understanding of system function and limitations, and the source of training/information.

While, overall, the technologies were viewed favorably by drivers, the data also indicated that drivers often revealed changes in their behaviors — possibly reflecting some adaptations to the technology (Figure 6). Moreover, drivers often exhibited an incomplete or inaccurate understanding of the systems in their own vehicles.

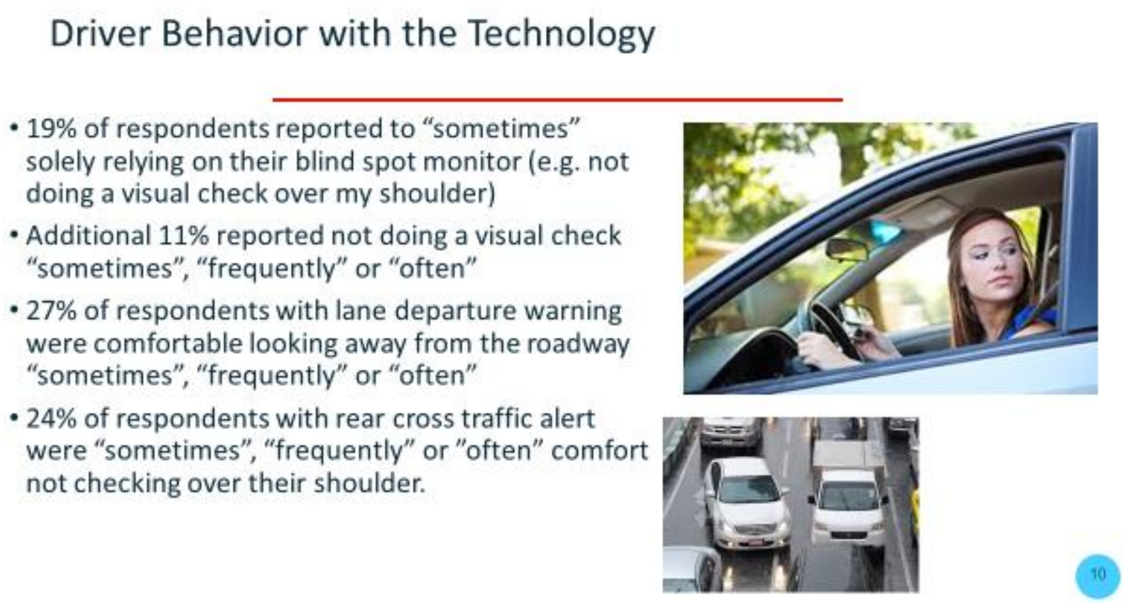


Figure 6. Example of self-reported changes in behavior in light of ADAS features (from Daniel McGehee, 2018, used with permission).

Dr. John Lee, University of Wisconsin-Madison

Dr. John Lee discussed the important role of trust in determining how drivers will behave with and accept AV technologies. He characterized trust as an attitude that an agent (here, the AV) will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability. More specifically, trust is based on the user's perception of the automation's purpose, process and performance and, ideally, the degree of trust in the system is appropriately aligned with the capabilities (or trustworthiness) of the system.

Dr. Lee also presented some recent analyses of open-ended responses from JD Powers 2017 U.S. Tech Choice Survey. Using a topic modeling approach, it found that concerns associated with AV could be categorized into human and technological issues and these also ranged from specific challenges to systematic ones. The topic modeling also shed some insight into the numerical ratings provided by such surveys, offering a potentially useful tool for future research efforts. Dr. Lee also described how trust is impacted by experiential, relational and societal factors (Figure 7) and, thus, what and how to communicate information to users and consumers of AV is an important part of this process.

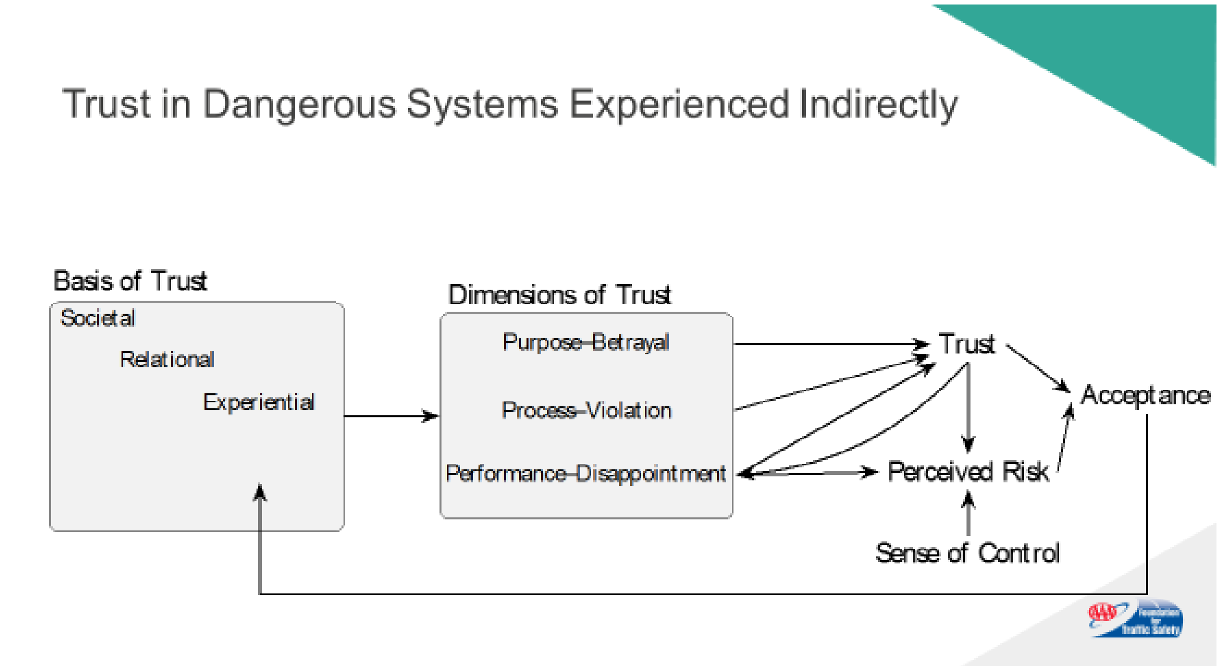
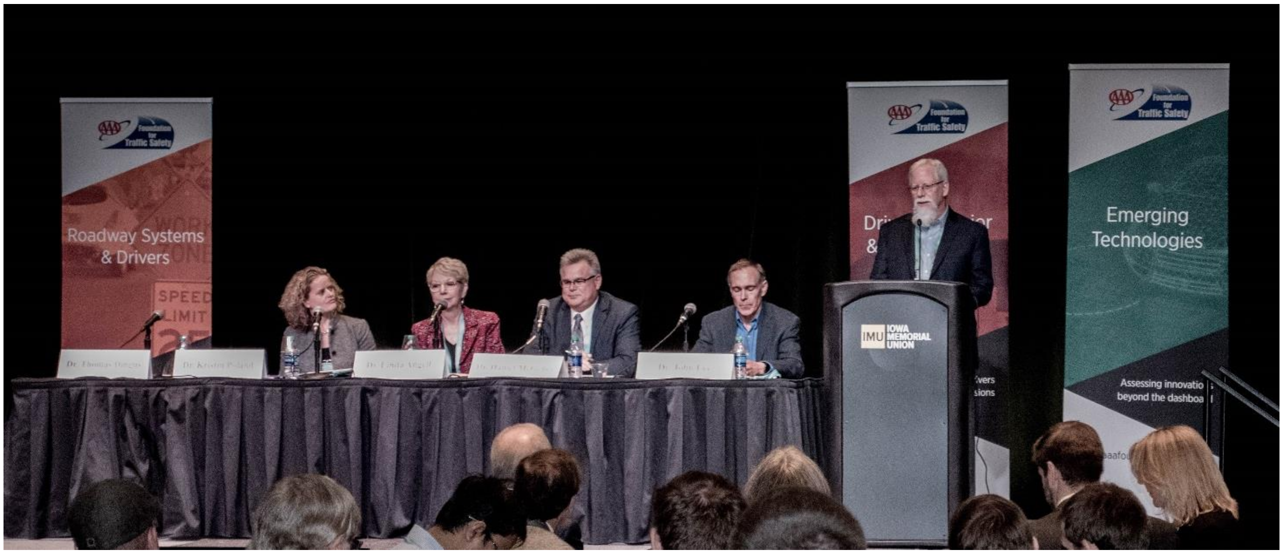


Figure 7. Factors influencing trust and acceptance of systems (from John Lee, 2018, used with permission).

Panel 2 Discussion

Following a concise overview by Dr. Horrey of the key points raised by each of the panelists, attendees had an opportunity to ask questions. A major theme in these questions and the discussion that ensued was the need to make the driver-vehicle interface transparent, especially with respect to the system's communication to the driver of its current state — for example, by using algorithms to communicate uncertainty to the driver rather than to mask it. Another related suggestion was that ADAS technologies could provide a safety net/redundancy for an automated vehicle system, similar to how they have been designed to provide redundancy for failures on the part of the human driver. Other major topics discussed included how drivers should be trained with respect to driver assistance and vehicle automation technologies, what can be learned from other domains regarding how to foster trust in vehicle automation, and the need for constant evaluation of systems in both pre-deployment and post-deployment.



Day 2: Breakout Tasks and Outcomes

Following a model similar to the 2017 forum, the main charge on Day 2 was to break into small groups and discuss two main questions, then prioritize and present responses back to the overall group. Nine groups were created, and a diverse set of backgrounds and job roles was included in each (e.g., representatives from research/academia, industry, government, etc.). Groups were provided with a short document that outlined the major themes from the 2017 forum (Appendix C). The specific questions were:

1. Based on research needs identified in the 2017 Forum and the discussion from Day 1 of the 2018 Forum, please identify a short list of research needs on:
    - Impact of vehicle technologies and automation on vulnerable road users.
    - Impact of vehicle technologies and automation on driver behavior and performance.
2. How should these research needs be addressed? Who should address these research needs? Are there any potential consortiums or collaborations that could be established to facilitate these research needs? When should these needs be addressed (e.g., priority timeline)?

Information from the group presentations, the notes from group interactions and feedback gleaned from individuals have been distilled and synthesized in the sections below.

Research Needs

In the section below, the discussion topics and specific research needs have been grouped into broad categories. It is important to note, however, that these categories are not mutually exclusive and many of the specific topics have relevance in more than one category.

Mapping Scenarios and Technologies

One common theme that emerged from the group discussions involved our fundamental understanding of the interplay between vehicles and other road users and the role of technology in addressing conflicts. That is, there was a need to map specific crash configurations, use-case scenarios or specific user needs with the types of technologies that could effectively address them. For example, focusing on the most common crash configurations for novice drivers is a useful way of prioritizing technologies designed to mitigate them. Alternatively, these scenarios would be used to inform the design and tuning of the technologies. For example, knowledge of certain pedestrian behaviors — even if infrequent and less predictable — is useful when conceiving of the technical and sensing needs for a given AV system.

The mapping of these scenarios to technologies was often considered a precursor to other research needs. Some of the more specific discussion points included:

- The need to carefully define the vulnerable road users (VRU) populations of interest (e.g., age, capabilities, impairments, modes of transportation, etc.). Also assessing the needs of these individuals from a mobility and safety perspective as well as their existing barriers to transportation.

- How can automation be used to support these individuals or address their challenges/barriers? In doing so, researchers and other stakeholders must carefully consider varying levels of automation as well as the target domains/scenarios (i.e., ODD).
- Use real-world crashes involving VRU to identify ways in which crashes could have been avoided — independent of specific technologies. Such "what-if" scenarios could inform subsequent research needs as well as the tuning of different AV algorithms.
- What are the scenarios that AV must accurately predict and address? How will the diversity and wide-ranging behaviors of different road users be dealt with? How will emergent modes of travel by VRU (e.g., electronic scooters and others yet to come) be dealt with?
- Mapping of sensor technology to the types of VRU crashes that commonly occur and exploring the best means of conveying critical information to all parties involved.
- A consideration of countermeasures is not limited to the AV technology itself. This can also be grounded in related policy and cultural (e.g., norming) aspects as well.
- What countermeasures can be applied to VRU to safely interact with AV?
- Developing and refining methods to assess interactions between vehicles and VRU. Also, more refined outcome measures (and surrogate measures, as appropriate) are needed.
- What do routine, real-world interactions between drivers and pedestrians/cyclists look like? Do drivers change their behavior after they become aware of a pedestrian or cyclist?
- Use-case and crash scenarios should also consider the role of distracted, drunk and drug-impaired pedestrians/cyclists.

Human-Machine Interface Design, Adaptive Automation and Accessibility

System design and the human-machine interface (HMI) was another common thread. The design of the HMI was often implicated in the quality of mental models, system acceptance and use, training needs, and accessibility of the AV, among others. It was also widely acknowledged that vulnerable road users, as a group, potentially constituted high variability and individual differences. As such, understanding the variability within these groups as well as their individual needs is an important consideration in the design and functionality of the systems. In this vein, the topic of adaptive automation was prominent during the discussion as were provisions for vehicle and system accessibility for certain VRU.

- How can HMI be made intuitive for vulnerable road users (VRU) such as novice and elderly drivers?
- What is the best means of conveying uncertainty regarding AV operations through HMI?
- Does uncertainty information help with takeover time/quality? What is the impact on user trust and awareness?

- How can systems be designed “holistically” to make sense to the driver, impose minimum cognitive load and be “good” (generally speaking)? What are the different ways in which OEMs could be incentivized with respect to the design of HMI?
- What design guidelines or principles should be considered for novice/elderly drivers, and/or drivers with other needs? Can existing human factors guidelines be expanded for AV space? Are there other pre-competitive courses that can aid in this space?
- What is the most effective way of making automation adaptive to different groups with physical or mental disabilities or different needs? (That is, not a one-size-fits-all approach.)
- What system functionality and information or system feedback is most important for different driver groups, including VRU?
- How can AV mode be communicated to different groups of VRU (as drivers)?
- Can information regarding the driver state be used to change the automation dynamically (i.e., tune the system behavior to the momentary capacity or state of the driver)?
- How do early adopters of technology compare with the general driving public?
- How does system transparency and explanatory systems (cf. reactive training) affect system trust and use? Is there a role for on-demand feedback in AV systems?
- Needing field work and/or naturalistic research on adaptive and smart headlights for VRU (e.g., pedestrians and bicyclists)
- What are the appropriate standards for accessible AV systems?
- What is the role of and what are the possible barriers to aftermarket vehicle adaptations to address specific user needs? How can these aftermarket devices interface with AV technology?
- If the driver’s intent is different from the machine’s intent and the machine is making a correct decision, should the driver be able to override the system?
- Expand understanding of wheelchair users from crashworthiness perspective — especially in light of evolution of the interior design of vehicles.

Communication of Intentions

Communication between AV and other road users is inexorably linked to the system design, though the focus is most often outside of the vehicle. This is especially critical when considering vehicle-pedestrian interactions. Although there is emerging research on external HMI directed at pedestrians, there are still many important research needs related to the communication of AV intentions.

- What, how and when should AV communicate with pedestrians and other road users (e.g., external HMI, smartphones, infrastructure)? How can these communications be informed by current interactions and practices? What types of scenarios are especially problematic?
- How do different forms of AV communication influence pedestrian behavior?
- How do pedestrians interpret communication from AV in the absence of other cues? Can information drawn from other research domains (human-robot interaction) be informative?

- How and what should AV communicate? What is conveyed in routine (non-AV) interactions and can these form a basis for AV interactions? What scenarios are most problematic for AV communication? Can or will AV communication impact or influence pedestrian behaviors?
- Would there be some new external HMI that could be beneficial for VRU? This could be applicable to both AV and manually driven cars, though it is unclear whether it is important that VRU be able to distinguish AV from traditional cars.
- How much external information is too much?
- Can external cues be presented to specific VRU, such as using directed white noise instead of omnidirectional beep?

Mental Models, Acceptance and Unintended Consequences

As in the 2017 forum, drivers' mental models of automated systems were prominent in the discussion and were tightly linked to many of the other categories presented. A mental model refers to a given driver's perception and understanding of the automated system they are interacting with — whether accurate or inaccurate (in degrees). The quality of one's mental model can influence the degree to which they trust, accept and use the system but can also lead to other unintended consequences — both on the part of the drivers of AV as well as by other road users.

It is important to recognize that vulnerable road users (e.g., older drivers, novice/teen drivers) who are driving the AV-equipped vehicles might have special needs related to their understanding of the system. For example, novice drivers who are still learning the physics of how vehicles respond in different circumstances might have unrealistic expectations regarding the performance of AV (even beyond the unrealistic expectations observed in more experienced driver groups). Equally, other road users (e.g., pedestrians and bicyclists) will also have their own mental model of how the AV around them will behave, and this will influence their own actions and behaviors. For example, pedestrians who believe that an approaching AV has the sensor technology and the capacity to stop for them might be more prone to step out in front of it.

Some of the specific questions raised:

- What is the quality of mental models regarding AV technology in the general public and in different VRU, in particular? Will they understand how to disengage AV systems, where relevant?
- How does different naming and branding impact mental models in VRU? Similarly, how do variations in the implementation of AV technology across make/model impact mental models?
- How do changes in the systems (e.g., through over-the-air updates) impact the mental models of VRU?
- What specific needs do different VRU have and how do they impact acceptance of the technology?
- What influence does user/consumer acceptance have in product development?

- How do different interfaces or system feedback impact trust in the system?
- Is gamification a means towards higher user acceptance?
- What is the willingness of different VRU to adopt systems that can collect data, given privacy concerns?
- What kinds of system misuse will occur by nondrivers of AV (e.g., by pedestrians in the vicinity of AV)?
- How will system misuse and other unintended consequences change over time and as technology progresses?
- How will older drivers, especially the oldest age groups, perceive higher levels of AV technology and how will they use it in real-world situations?
- Do advanced technologies actually extend safe driving in older adults?

Training, Education and Feedback

Driver training, consumer education and feedback continued to be an important area for research. The forum showcased the broader implications for the diverse driving population (with full consideration of wide-ranging vulnerable road users) as well as the need to promote understanding of AV even among people who do not own or use the technology.

- Knowledge and understanding of what tasks or AV features are essential for safe and proper use of a given system. What kinds of information do other road users need regarding AV?
- What is the nature of skill degradation and overgeneralization in different VRU following exposure to AV?
- What information is needed to update driver training and what is the most effective medium to convey this information? Can nontraditional training (i.e., structured feedback) of driver behavior and vehicle tech intervention improve driver safety and understanding?
- How can we effectively train the driver to take appropriate advantages of vehicle systems? How can the vehicle provide just-in-time or on-demand help/tutorial to the driver (e.g., car could push the appropriate video to your phone or to the center console)? Thus, training and education becomes an aspect of the HMI.
- How can we effectively train the driver to become proficient with an AV? Can gamification concepts be used (e.g., leveling up, achievements)?
- Trip summaries at the end of the drive could help to avoid the distraction of presenting it in the moment.
- Can these concepts address the rental car problem?
- How do transparency and explanatory systems (reactive training) affect trust?
- What are the training needs of older drivers concerning AV technology?

Driver-State Monitoring

Although driver-state monitoring is a concept that applies to all drivers, its role for vulnerable road users is particularly important — especially as drivers of varying levels of fitness and capacities are engaging with AV technology. Driver-state monitoring can be useful in guiding system responses in different circumstances, through adaptive automation. It was also emphasized as an important aspect of crash investigations related to AV use (and potential misuse). Among the questions raised on this topic:

- How do we reliably measure driver state?
- How do we use information about driver state to determine driver readiness in different scenarios? As an extension of this, how can this information be used to tune the intervention to the situation?
- How does the vehicle respond to different levels of driver impairment? At what point should it intervene? Data is needed to help designers determine when drivers can respond.
- Better understanding of what information is conveyed to driver and identify when there is overload.
- In terms of EDR (black boxes), can information regarding the driver as well as the AV state be recorded? This information can inform where systems are used and how to integrate them into crash reporting.
- What is the role and impact of commonly used medications on driving performance, and how can this information can be applied in driver-state monitoring?

Roadway System

A number of questions and issues were raised concerning the broader roadway system for AV and other road users. Many of these related to the use of infrastructure to enhance the availability and delivery of critical information.

- What types of aid for the driver could be implemented into the infrastructure?
- How can dynamic mapping be leveraged?
- What are regional differences (e.g., local governments) regarding the implementation and reporting needs for AV?
- What are other drivers' reactions to AV with no passengers (versus ones with passengers)? What is the prevalence and impact of "bullying" of AV?
- What do cities need to do to get ready for AV?
- How can critical information to and regarding emergency responders be conveyed?
- General need for more research on mixed fleets, both with respect to vehicles with different levels of automation sharing the road with one another, and also with respect to a given individual potentially driving or using multiple vehicles with different levels of automation.
- How can street and on-board lighting, coupled with integrated systems, help address pedestrian-vehicle crashes? In-depth analysis of pedestrian crashes can help provide insight into this topic.
- What are the best means of retrofitting infrastructure to support AV? (e.g., lane markings, signage). How do these changes impact other non-AV drivers?
- How do new forms of mobility (e.g., electric scooters) impact safety and interactions with or by VRU and AV?

Closing Remarks

This forum, the second of its kind, was convened with the ultimate aim of promoting engagement and discussion among key stakeholders from research, industry, government and other entities. Vehicle technologies and automation are progressing rapidly and it is important to keep sight of those research questions that will impact the safety and success of these systems. It is important that such research offer critical insight into how driver behavior and performance changes in light of these systems as well as regarding needs and interactions of and with vulnerable road users. Both of these dimensions were showcased in this forum.

Many of the research needs touched on similar themes as those in the 2017 forum (see Appendix C). This serves as a salient reminder that there is much work to do. However, it is encouraging that many research efforts are underway and progress is being noted. New questions that emerged in the most recent forum, including those related to the special consideration of VRU and other driver behaviors, will hopefully promote further efforts by students and academics, research institutions, OEMs or other stakeholders, to pursue answers to some of the questions.

Appendix A: List of Organizations That Participated in the 2018 Forum

AAA Foundation for Traffic Safety
AAA National
AAA Northeast
AAA Western & Central New York
Alliance of Automobile Manufacturers
Auto Club Group
CarProfConsulting
Children's Hospital of Philadelphia
Federal Highway Administration
Hyundai American Technical Center
International Association of Traffic and Safety Sciences
Iowa Department of Transportation
MRI Global
National Highway Traffic Safety Administration
National Transportation Safety Board
Osaka University
State Farm
Touchstone Evaluations, Inc.
Toyota Motor North America
Transport Canada
U.S. Department of Transportation
University of Alabama at Birmingham
University of Iowa Injury Prevention Research Center
University of Iowa National Advanced Driving Simulator
University of Leeds
University of Michigan
University of Nebraska Medical Center
University of Puerto Rico at Mayaguez
University of Utah
University of Wisconsin
Virginia Tech Transportation Institute
Volpe National Transportation Systems Center
Westat
Wichita State University
Yahara Softwarex

Appendix B: 2018 Forum Agenda

AGENDA

Thursday, November 8, 2018

8:30 AM - 9:00 AM
Continental Breakfast

9:00 AM - 10:30 AM
General Session
Group Assignment Discussion

10:30 AM - 10:45 AM
Refreshment Break

10:45 AM - 12:00 PM
General Session Resumes
Group Discussion Reports & Feedback from Expert Panel

12:00 PM
Forum Adjourns

12:00 PM - 12:30 PM
Boxed Lunch

12:30 PM - 3:30 PM
Optional Tour: National Advanced Driving Simulator (NADS)
Bus shuttles will transport attendees from the Iowa Memorial Union and Hilton Garden to NADS every 30 minutes between 12:30 and 2:30 p.m. and back between 1:30 and 3:30 p.m. Attendees are encouraged to come and go as their schedule permits.

NADS is located at 2401 Oakdale Blvd. in the University of Iowa Research Park (15 minute drive from forum location). Free parking is available.

THANK YOU TO OUR SPONSORS

Public Affairs
TRB Transportation Research Board
The National Advanced Driving Simulator, The University of Iowa
SAFER SIM
The Auto Club Group
Life Insurance Company

Wi-Fi Access

To access complimentary Wi-Fi during the forum, please follow the instructions below:

- Select the network "UI-Guest"
- There is no password required

Foundation for Traffic Safety
The University of Iowa

2018 FORUM: IMPACT OF VEHICLE TECHNOLOGIES AND AUTOMATION ON USERS

November 7-8, 2018
Iowa City, IA

Welcome to the 2018 Forum: Impact of Vehicle Technologies and Automation on Users, hosted by the AAA Foundation for Traffic Safety and the University of Iowa.

Building upon the momentum from the 2017 Forum, this year's gathering will examine the likely impacts of vehicle technologies and automation on vulnerable road users (including teen and senior drivers) as well as driver behavior and performance. This is an exciting era for transportation and we regularly hear various types of information related to vehicle technologies and the potential of autonomous vehicles from different media outlets. However, not all information being shared about the new transportation era is consistent and accurate. As a community of transportation professionals, we have the opportunity to shape the development of future transportation by identifying research needs and gaps, carrying out solid work and finding solutions, and disseminating accurate information about the new transportation era to others. This Forum provides a platform for stakeholders from academia, government, and industry to gather, share insight, and build partnership. Thank you for your participation!

Sincerely,

C. Y. David Yang, Ph.D.
Executive Director
AAA Foundation for Traffic Safety

AGENDA

All sessions and meals will take place in the Main Lounge of the Iowa Memorial Union unless otherwise noted.

Wednesday, November 7, 2018

8:30 AM - 9:00 AM
Registration and Continental Breakfast

9:00 AM - 9:30 AM
Opening General Session
Welcome & Forum Objectives
Dr. David Yang, AAA Foundation for Traffic Safety
President Bruce Harreld, University of Iowa

9:30 AM - 9:45 AM
Review of Key Research Needs from the 2017 Forum
Mr. Brian Tefft, AAA Foundation for Traffic Safety

9:45 AM - 10:45 AM
Panel 1: Impacts on Vulnerable Road Users
Mr. Kevin Dopart, ITS Joint Program Office, U.S. Department of Transportation
Dr. Joe Kearney, University of Iowa
Dr. Don Fisher, Volpe Center, U.S. Department of Transportation
Dr. David Eby, University of Michigan
Dr. James Jenness, Westat

10:45 AM - 11:00 AM
Refreshment Break

11:00 AM - 12:15 PM
General Session Resumes
Facilitated Panel 1 Discussion
Facilitator – Dr. Tara Kelley-Baker, AAA Foundation for Traffic Safety

12:15 PM - 1:15 PM
Lunch and Networking

1:15 PM - 2:15 PM
Panel 2: Impacts on Driver Behavior and Performance
Dr. Tom Dingus, Virginia Tech Transportation Institute
Dr. Kristin Poland, National Transportation Safety Board
Dr. Linda Angell, Touchstone Evaluations
Dr. Dan McGehee, University of Iowa
Dr. John Lee, University of Wisconsin

2:15 PM - 2:45 PM
Refreshment Break

2:45 PM - 4:00 PM
General Session Resumes
Facilitated Panel 2 Discussion
Facilitator – Dr. Bill Horrey, AAA Foundation for Traffic Safety
Summary of Day 1 and Plan for Day 2

6:30 PM - 8:30 PM
Forum Dinner at Cedar Ridge Winery*
Hosted by AAAFTS and University of Iowa
Winery is located at 1441 Marak Road Northwest, Swisher, IA

*Round trip transportation is available from Hilton Garden Inn Downtown, 328 S. Clinton Street, Iowa City, departing from the hotel lobby at 6 p.m.

Appendix C: Research Needs Identified from the 2017 Forum

2017 FORUM ON THE IMPACT OF VEHICLE TECHNOLOGIES AND AUTOMATION ON USERS: KEY RESEARCH AREAS AND THEMES

INTRODUCTION

On November 7-8, 2017, the AAA Foundation for Traffic Safety and the University of Utah hosted a forum to discuss and identify future research needs related to the impact of vehicle technologies and automation on drivers and other users of transportation systems. The forum was attended by academics, automobile manufacturers and industry representatives, government agencies, advocacy groups, and other research organizations. The forum was co-sponsored by AAA Public Affairs, the University of Iowa National Advanced Driving Simulator, and the Transportation Research Board. This document summarizes major research areas and themes identified by the participants of that forum.

KEY RESEARCH AREAS AND THEMES

Mental Models

- How are mental models developed? What are the most influential factors?
- How do naming/branding/marketing influence mental model development?
- What are the safety consequences of inaccurate mental models?
- What are the causes and effects of mode confusion, and how can they be minimized?
- What scenarios lead to "Automation surprises?"
- How do people respond to software updates?
- What happens when a driver is exposed to different vehicles with different features?

Automation Trust & Acceptance

- What is the relationship between trust, comfort, and confidence in automated systems?
- What measures can be taken to calibrate driver comfort and choices relative to system capabilities?
- How do user education & training impact trust & acceptance?
- What are the barriers to adoption and use of advanced systems?
- How can dread risk be avoided or mitigated?

The Technical Report from which the contents of this Fact Sheet were derived is available online at: http://aaafoundation.org/2017-forum-impact-vehicle-technologies-automation-users-summary-report/

Automation Misuse & Unintended Consequences

- How does user perception affect misuse?
- How can user expectations be matched to vehicle capabilities (in general and specifically in context of hand-over)?
- What system functions & circumstances will lead to negative driving behavior?
- What is the prevalence and impact of *intentional* misuse of systems?

AAA Foundation for Traffic Safety

Design & Human-Machine Interface

- How can we build intuitive systems that do not require a manual?
- What are the roles and safety implications of customizable / adaptable displays or features?
- What is the safety benefit of multiple levels of redundancy? How many layers are necessary?
- How do assumptions made by engineers in the design phase percolate into inappropriate system use?
- How can systems model human intent to facilitate interaction with other road users?
- How can systems leverage human capabilities to enhance overall system performance & value?
- Can simulation be used to train AVs in edge case scenarios?

Education & Training

- How much knowledge / training / depth of understanding do drivers need to use systems safely, overall and in relation to different levels of automation?
- When, where, how, and by whom should training be delivered?
- Are videos effective? Simulation?
- Can we leverage alternative approaches to education/training (e.g., like video game tutorial mode that must be completed before system can be used.)
- How can drivers be incentivized to learn how to use technology?
- What is the life cycle of skill degradation? How can this be mitigated?

Mixed Fleet & Infrastructure

- What are the anticipated safety outcomes that result from mixed fleet? (e.g., might the risk of certain types of crashes increase?)
- How will vehicle automation affect the behavior & safety of pedestrians, cyclists, and other human drivers on the road?
- How do risk factors change over time with market penetration?
- How will AVs react to "bullying" by human road users?
- What is the impact of infrastructure degradation on performance and safety of automated systems?
- How will intermittent software updates for specific vehicles affect overall system function & coordination? What are the implications of that when we are expecting these systems to communicate with each other?

Driving Populations & Individual Differences

- Who is eligible to "drive" with various levels of automation? (e.g., the blind? cognitively impaired?)
- How do special populations interact with these systems? (e.g., teens, elderly, risk-takers, etc)
- How can we address socioeconomic concerns in implementation of the technology?
- How do we motivate different driver groups to want to learn about vehicle automation?
- How will new/inexperienced drivers interact with these systems?

Measurement

- What are the most appropriate metrics for real-life misses (i.e., edge cases)? How can they be quantified?
- How generalizable are the results of current studies, especially those from simulation settings?
- What data comes back to developers/community to improve the technology and safety?
- How can new technologies be leveraged to learn more about drivers themselves?
- Can naturalistic driving data be used to determine what kinds of misuse is occurring? Is there enough data?
- How can VIN information be improved to facilitate understanding of technology installed in vehicles?