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# Driver Assistance Systems and the Transition to Automated Vehicles: A Path to Increase Older Adult Safety and Mobility?

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As operators of motor vehicles, drivers have been described as "outdated . . . with Stone Age characteristics and performance . . . controlling a fast, heavy machine in an environment packed with unnatural, artificial signs and signals" (Rumar, 1981). Despite our anatomical, physiological, and perceptual shortfalls, the fatality rate in the United States hit a historic low of 1.1 fatalities per 100 million vehicle miles traveled (VMT) in 2011 (National Highway Traffic Safety Administration, 2011). Fatal crash involvement by VMT increases by age starting in the mid-60s (Insurance Institute for Highway Safety, 2011), and many individuals begin to curtail or stop driving. However, the cessation of driving due to advanced age comes at great cost. Age-related losses in the ability to drive equates, at best, to a forfeiture of personal freedom, reliance on the assistance of others to meet basic activities of daily living, and can lead to increased symptoms of depression (Marottoli et al., 1997).

Transitions in driving roles occur throughout one's lifetime. As medical conditions accrue, they can sporadically or permanently limit driving (Owsley, 2004). Women frequently cease driving earlier than men, and often while still fit to drive (Alsnih & Hensher, 2003; Siren, Hakamies-Blomqvist, & Lindeman, 2004). Widowhood can increase older women's need to drive (Braitman & Williams, 2011) at a time when this is particularly challenging. On the other hand, even as adults age, they are becoming increasingly economically able to purchase new vehicles (Coughlin, 2009). As a consequence of both the increased numbers and economic independence of older adults, innovations in personal mobility that mitigate the burdens of age will grow in value over the coming decades. A move toward new urbanism, including improved public transit systems and walkable streets and sidewalks, is an admirable vision that would help meet the growing needs of many older adults. However, it will require, at considerable cost, rebuilding or retrofitting the existing infrastructure at a rate that is not likely to meet the needs of today's aging boomers.

Fully automated or driverless cars, by contrast, represent a path that promises to enhance the mobility options of older adults within the existing infrastructure. However, many consumers do not clearly understand that while the basic building blocks of these systems are available today in advanced driver assistance systems (ADAS), fully automated or driverless vehicles are still on the distant horizon. For the foreseeable future, automated vehicle technologies, including ADAS, will continue to rely on a "responsible" driver to oversee the technology, capable of resuming control and having the foresight to make many (yet to be defined) strategic operational decisions. But because of their transformative promise and heavy news coverage, the prospect of automated cars has become a source of great hope for many. Some believe that fully automated cars, capable of navigating the roadways while the "operator" reads a paper or takes a nap, will be available within a few years. Unfortunately, that is not the case. Instead, there is work to be done to increase the awareness and education necessary to spur the purchasing of ADAS available today, which will support many older drivers' mobility and safety needs.

## The State of the Art of Automated Vehicles

The National Highway Traffic Safety Administration (NHTSA) classifies automated vehicle systems according to a scale that ranges from 0 to 4. A Level-0 system provides a degree of functionality that may provide information assistance but no automated control of the vehicle. Examples of currently available systems include forward collision warning, lane departure warning, and blind spot alerts. Level-1 systems provide automated control over one primary activity for safe vehicle operation during specific periods of time or across multiple independent functions. With Level-1 systems, the driver is expected to provide oversight over the automation and retain complete responsibility for safe operation. Existing technologies such as electronic stability control, adaptive cruise control, collision imminent braking, and lane keeping assist are Level-1 systems.

A Federal Motor Vehicle Safety Standard requires that one Level-1 system, electronic stability control, be provided as standard equipment on any 2012 model year or newer passenger vehicles sold in the United States. In essence, every new vehicle purchased in the United States has at minimum one form of an NHTSA-classified automated driving system. If utilized correctly, Level-1 systems can help older drivers maintain mobility. For instance, today's collision-imminent braking systems show promise in reducing the likelihood of collision, damage, and injuries (Insurance Institute for Highway Safety, 2012). Given the strong association between older adult frailty and fatality in automotive accidents (Li, Braver, & Chen, 2003), the increasing penetration of these systems has clear societal benefits.

Level-2 automated systems encompass two or more functions that can relieve some demands on the driver. While drivers cede active control of the vehicle to the automation in specific situations, they are expected to remain the responsible authority, capable of resuming control with no advanced warning. Examples of these technologies include systems that maintain lateral and longitudinal control of the vehicle in traffic jams or on highways. Level-2 automated systems, such as GM's Super Cruise (technology that controls lateral and longitudinal positioning in certain driving conditions), are expected to be in production shortly.

Level-3 systems will provide limited self-driving automation. As defined by the NHTSA, this level of automation allows the driver to cede "full control of all safety-critical functions" under certain conditions. The driver "is not expected to constantly monitor the roadway while driving." Systems are expected to provide the driver with ample time for transitions of control. The driver's responsibility in a Level-3 automated vehicle is not yet fully understood, as systems of these types are not currently available. Finally, Level-4 automation expects the driver, who is at this point perhaps better termed "passive supervisor," to provide limited guidance to the vehicle. This type of guidance may consist of setting a destination and then ceding all safety-critical driving functions to the vehicle. In essence, a Level-4 automated vehicle would be able to pick a passenger up at the curb and take her/him where s/he needs to go. It would transform business, safety, and urban design. There would no longer be a need for taxis, designated drives, and possibly even parking garages as car sharing could become the norm. A Level-4 car, frankly, would all but solve the mobility impairments associated with advancing age. But we are not there yet.

Rather, we are at a make-or-break moment on the road to a Level-4 automated vehicle, a critical juncture that hinges on a potential crisis of understanding and trust. Drivers are presently largely uneducated concerning the functionality of ADAS (Traffic Injury Research Foundation, 2013). They have little experience on which to form an accurate model of operation for these technologies, and no clear source of guidance on the appropriate conditions in which to operate or trust them. Without an understanding of the capabilities and limitations, drivers' experience of system performance will suffer, potentially eroding trust, negatively influencing the use of and the reliance on automation (Lee & See, 2004; Merritt, Heimbaugh, LaChapell, & Lee, 2013).

While many automated systems can help support drivers, misuse, disuse, and abuse of systems can negate or underrealize potential benefits of the technologies (Parasuraman & Riley, 1997; Seppelt & Lee, 2007). If we hope to fully realize the benefits of tomorrow's automated vehicle technologies, it will be imperative to provide today's drivers with effective tools for learning how and when to use ADAS. Utilization of these technologies should allow drivers to build models of operation and trust that flow naturally toward an increase in comfort with higher levels of autonomy. The alternative—a narrative of mistrust in ADAS in general—could have long-term ramifications for the market desirability and legal status of future innovations that, upon reaching full fruition, have the potential to solve many of today's transportation problems for the old and young alike.

To plant an appropriate seed of trust, we need to think hard about policy decisions that are required to encourage the successful adoption of Level-1 and Level-2 automated systems, before jumping ahead into Level-3 systems and beyond. Today's highly automated ADAS can help people stay safely mobile for longer into old age, and, with more widespread use, promise to increasingly reduce traffic congestion without requiring major infrastructure upgrades, and provide comfort and convenience unmatched by yesterday's cars. And, importantly, they will lay the framework—technically, psychologically, and legally—for the future of driverless vehicles.

## Human-Centered Considerations

A number of considerations will affect the development, success, and adoption of automated vehicles in the coming years. Of these, the issues that pertain most directly to improving transportation for older adults are questions of trust, education, and sociopolitical implications of automation related to technology failure.

The fact that we cannot create a perfect automated driving system is a major barrier to trust. No matter how close we get, unpredictable interactions between vehicle sensors, computational systems, and the environment will lead to a small but unavoidable rate of failure (Parasuraman, Hancock, & Olofinboba, 1997). Even if that failure rate is smaller than that of unaided human drivers, it may still be difficult for drivers—most of whom have an inflated impression of their driving abilities (McKenna, Stanier, & Lewis, 1991)—to trust a technology that could appear unpredictable (Lee & See, 2004). Worse, such trust deficits are exacerbated with age (Ho, Kiff, Plocher, & Haigh, 2005). Mistrust in technology and excessive trust in human capabilities together have a way of overshadowing statistics.

How can we overcome this deficit of trust in automated technologies, especially as it pertains to the car? Operator training has long been viewed as a critical component of successful automation (Parasuraman & Riley, 1997), and training may prove to be one of the key missing pieces in the deployment of today's ADAS. We have (Reimer, Mehler, & Coughlin, 2010) reported on work with Ford's Active Park Assist feature, a semi-automated parallel parking system. Prior to receiving any information about the system, participants reported that a semi-automatic parallel parking system was not overly likely to reduce their stress while parking. One can interpret this as an indication that the participants did not believe that they needed the help of automation. Nevertheless, after being extensively trained on the operation of the technology, we compared their behavior and physiology while parking with and without the aid of automation. When drivers approached a parallel parking situation, their stress level, as measured through the heart rate, was lower when the automation was available to help them. Tellingly, after becoming acquainted with the technology through the experiment, participants reported more positive expectations of how the technology could reduce stress, and many expressed interest in purchasing the system.

Interestingly, not all effects were positive. The use of turn signals to indicate a driver's intent to park decreased with the use of automation. While details of signal operation were not addressed in the training, this observation illustrates a potential disconnect between the users' and designers' models of operation. When people are extensively trained in the use of a technology, perhaps well beyond the training provided by a car manual or a YouTube video, they often can better grasp the limitations of a system and experience its benefits more clearly. Without appropriate exposure, however, they have limited experience in which to ground their expectations.

Backup cameras are another example of how more automation in the car requires more education, not less. Backup cameras are designed to support the driver's eyes and mirrors, not to replace them. But older drivers, often because of impairments in neck and back mobility, tend to rely less on direct glances to the rear of the vehicle and more fully on cameras to back up (Jenness, Lerner, Mazor, Osberg, & Tefft, 2007). When a crash occurs due to an operator overly relying on the backup camera, it may be due to the operator's failure to understand (or recall) limitations in the view provided by the camera. Education on how to use a backup camera—and other ADAS—could help prevent such issues, but the infrastructure to accomplish this education does not exist at present.

In addition to training on how to use automation, we also need to educate drivers on when to use it. Take adaptive cruise control—should operators use it in the snow, the fog or while approaching an exit ramp? The consequences of making the wrong decision, such as sudden acceleration of a vehicle with adaptive cruise control on an exit ramp, can be scary and erode trust. One of the challenges of automation is the fact that the more self-sufficient a system becomes, the less the operator is involved. Ideally, in addition to promoting a working knowledge of when to use automation, we would find a way to educate operators about some of the key theoretical underpinnings of the technologies they are using (Rudin-Brown & Parker, 2004). In such a scenario, a user of adaptive cruise control would be more likely to understand that it is designed to follow a vehicle at a set distance, and that when there is no car ahead, the system tries to accelerate to the preset preferred speed. Unexpected acceleration can create a potentially unsettling discomfort with the technology. An educated consumer would be more likely to disable the system before turning out of traffic and onto a ramp.

We are at a moment of potential crisis because some are now pushing technical and legal envelopes by predicting deployment of fully automated vehicle within a few years. Given the learning curve associated with new technologies, many, especially older drivers, are already primed to reject these systems and thus their benefits. This predisposition can be remedied through education, but it would almost certainly be heightened should the worst—a lethal crash or a broad failure in an ADAS—take place today or tomorrow. “The first time that a driverless vehicle swerves to avoid a shopping cart and hits a stroller, someone’s going to write, ‘robot car kills baby to save groceries,’” said Ryan Calo, a law professor at the University of Washington who co-founded the Legal Aspects of Autonomous Driving Project at Stanford (as quoted by Cain Miller & Wald, 2013). In the event of such an accident, drivers who are fearful of the unknown may choose to group basic ADAS inappropriately with higher-level automated systems, and rely on ADAS less. Once an individual questions their trust in a technology, s/he is more likely to turn it off, reducing potential benefits and creating apprehension in future use.

Given the substantive safety benefits automated technologies have to offer older adults, and the mobility benefits fully automated transportation may offer in the future, there is a need to increase consumer understanding and trust in today’s driver-assistive technologies through interface design and education.

## Recommendations

Key safety advances for older drivers may be realized through increased utilization of vetted (in production) lower-level (l & 2) vehicle automation. The successful deployment and adoption of these systems will play an important role in the successful transition of drivers toward vehicles with higher levels of automation. It is critical, however, that automation be developed in a manner that builds upon and establishes realistic driver expectations and mental models of operation (including system limits and use constraints). In essence, technical advances may only succeed if drivers can successfully acquire the skills necessary for successful operation.

Although automated vehicle technologies will ultimately save lives, there may be unavoidable issues, and even loss of life, on the way to full automation. It is essential to begin framing the issue of automation as a long-term investment in a safer, more convenient future that will revolutionize, in particular, the experience of old age.

Policymakers, researchers, and industrialists should focus on developing a cohesive vision for increased vehicular automation that promotes, where effective, the utilization of current safety systems to reduce traffic fatalities, personal injury, and property damage. While such a goal can be achieved through current Federal Motor-Vehicle Safety Standards, it will require the development of new sources of data to support regulation. Naturalistic data recorders that can capture detailed data on how and where drivers operate advanced safety technologies will be critical to describing how the utilization of driver assistance systems impacts crash causation and occupant safety. While the benefits of such tracking technologies are great, they will not come without cost, encroaching upon issues of personal privacy, data security, and liability.

Vehicle interfaces need to be optimized to support driver attention, not fight for it. In essence, technologies are needed that help monitor, manage, and motivate drivers, so that they can best achieve a critical balance of attention between over- and under-arousal (Coughlin, Reimer, & Mehler, 2011). Multi-modal interfaces need to provide drivers with effective methods to personalize interactions, so that an individual can more optimally allocate attention across channels, that is, self-selecting how to receive critical feedback.

Finally, a new national driver education system is needed. This system needs to stretch well beyond today’s models to address continual skill development with vehicle systems, regulation, and modes of operation. From a policy perspective, it is unclear if the current state-based licensure system is effectively prepared to support such a radical change in driver education requirements.

The policies we should develop to address these issues will require investment in basic research on human–machine interaction, and, more specifically, on drivers’ relationship with automated vehicles. Such research must explore how necessary advances in interfaces will fit within current guidelines for driver distraction and establish a clear understanding of how the safety risks associated with distraction and fatigue change with increased ADAS. Until relatively recently, the basic human–machine interface has changed very little in the history of the car, but it is about to transform significantly.

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We should make sure that we are prepared when key aspects of the driving experience, which we currently take for granted, change with increasing levels of automation in the vehicle. In summary, as we prepare the consumer for the realities of highly automated driving, the first part of that process must be educational, building trust and proficiency in today’s ADAS, and charting a vision toward the policies, technologies, and human-centered interactions that will support tomorrow’s driverless vehicles.

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