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Driver Monitoring Systems: Design Considerations for Aging Drivers

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ABSTRACT

A number of automotive manufacturers including General Motors and Tesla offer vehicles with advanced semi-autonomous driving functions that the driver is expected to monitor. Monitoring by the human driver is essential given that these systems are known to have difficulty handling driving situations that human drivers negotiate easily. The human operator must, however, adjust to this new supervisory role of monitoring system operations rather than traditional driving. Additionally, drivers may trust the automation too much, believing the systems are more capable than they are and not actively monitor the operation of the semi-autonomous systems. This belief may be engendered by the use of terms like “self-driving” or “drive pilot” in vehicle marketing materials. In response to these concerns, automotive manufacturers have developed driver monitoring system(s) (DMS) that assesses the driver’s attentional engagement in the driving process and alerts them when it determines they are not attending to the vehicle’s operation. Driver attention is assessed by monitoring their eye-gaze direction, head pose, steering wheel torque input, and facial action units. During the aging process, there are many changes in perceptual, cognitive, and musculoskeletal systems that may not have been addressed in the design of the DMS. An example of these limitations include hearing or vision impairments, which could make perceiving warnings presented by the DMS more difficult. The potential limitations of DMS will be discussed, as well as ideas for future research, which encourages consideration of older adults in interface design and discusses trends in technology adoption by older adults.

Keywords: Driver monitoring systems, Interface design, Aging

INTRODUCTION

Vehicles are increasingly equipped with a range of Advanced Driver Assistance Systems (ADAS). Some of these features include lane keeping assist system (LKAS), adaptive cruise control (ACC), and automatic emergency braking (AEB). The LKAS aids the driver by providing steering assistance so the car does not depart from its lane. ACC works by adjusting the speed of the vehicle to match a driver defined target speed and automatically slows and maintains a specific following distance if it detects a car ahead that is driving more slowly. AEB forces the vehicle to stop when an obstruction enters the vehicle’s driving path. Users are often unfamiliar with the operation and limitations of these systems, leading drivers to reduce their monitoring of the roadway because they believe the systems are more capable than they are (Parasuraman and Riley, 1997). Marketing materials that use terms like "drive pilot" and "self-driving" give drivers a false impression that the car has the ability to drive itself (Abraham, et al., 2017). In response, manufacturers have developed Driver Monitoring Systems (DMS) that evaluates the driver's behaviour to infer their attentional engagement with the driving task and preparedness to take manual control of the vehicle in the case of an ADAS failure.

The effectiveness of a DMS may vary for users of different ethnic or demographic groups. For instance, a recent study found that several state-of-the-art object detection models showed uniformly poorer performance when detecting pedestrians of darker skin tones (Wilson et al., 2019). The possibility exists that object detection algorithms used in ADAS and DMS might exhibit similar limitations. Similarly, the performance of facial recognition applications have also been shown to vary depending on the ethnicity of the faces (Grother, Ngan & Hanaoka, 2019). Understanding current DMS limitations such as these detection errors is valuable when evaluating future system designs and upgrades. The hope is to develop an inclusive system that can cater to all drivers.

The ADAS technology can increase safety and functionality for older drivers and drivers with disabilities. However, aging adults represent a segment of the user population that is not always considered when designing modern systems, such as ADAS, even though they might stand to benefit the most from the use of this technology. This is problematic because many aging adults experience a range of age related physical, sensory, and cognitive changes. Consideration of these changes increases the likelihood that these systems will perform more accurately for the users regardless of their ethnicity, age, and gender. In this paper, we will explore important design considerations for aging adults, provide suggestions for future research such as improved interface design, and discuss trends in technology adoption by older adults.

DRIVER MONITORING SYSTEMS (DMS)

The design and operation of a DMS varies by manufacturer, relying on sensors to detect steering movement or visual features such as the driver's head and eyes to calculate parameters such as head position, eyelid closure, and eye gaze direction. The sensors are often installed in the A-pillars—the structural pillars on either side of the windshield—or on the instrument cluster (Ford Motor Company, 2022; GMC, 2022; Khan & Lee, 2019; Nissan, 2022; Volvo, 2019). Smart Eye is an example of one company that provides hardware (such as cameras) and software used by original equipment manufacturers (OEMs) in the design of DMS. These sensors can identify the presence and position of the driver, detect dangerous behaviors such as eating, drinking, or mobile phone use, use facial expression analysis to identify the driver's mood, use key body points to track driver interactions with objects in the vehicle, detect distraction and drowsiness, and even detect drivers states such as unconsciousness or intoxication (Driver Monitoring System, 2023). Aside from visual sensors, another common sensor type is pressure sensors in the steering wheel that can detect the driver's hands and torque sensors on the steering column which detect steering inputs. Both of these inputs are believed to reflect driver engagement with the driving task by ensuring that the driver has their hands on the steering wheel (Ford, 2022; GMC, 2022). Nissan uses an advanced form of torque monitoring by monitoring steering wheel torque inputs for several minutes upon reaching a target speed, then continually comparing the driver's input to this baseline to detect driver drowsiness as indicated by an increase in sudden sharp steering inputs (Nissan, 2022). If driver inattention is detected, the systems use different types of alerts to prompt the driver to re-engage attention on the driving task. Commonly employed alerts include visual alerts like flashing lights, verbal auditory alerts and tones, and haptic feedback (Huang & Pitts, 2020).

Each DMS has operational challenges or limitations. Systems monitoring driver eye and head position can be adversely affected by environmental conditions such as bright sunlight and drivers wearing sunglasses or eyeglasses which may impair the system's ability to detect the drivers' eyes. Similarly, systems that rely on localizing facial features to identify head position are less robust when the driver is engaged in conversation, wears eyeglasses, closes their eyes, or rotates their head (Jo et al., 2011). Finally, the reliability of the systems can also be affected by driver ethnicity as previously noted. Additionally, it is not clear if driver eye health or presentation affects the performance of DMS. This is of concern as drivers, especially older adults, may be monocular, strabismic, experience nuchal rigidity, or wear corrective lenses.

The conditions noted above vary in frequency across the population and some are more common with age. Below we discuss how changes in physical, cognitive, and musculoskeletal function associated with aging may impact the use of a DMS by older drivers.

DMS INTERACTIONS WITH AGING

Interactions With Vision Changes

Changes in visual ability and function with age are ubiquitous. These changes include reduced near and distance visual acuity and contrast sensitivity (Stone et al., 2018). Visual acuity reflects the ability to resolve fine high contrast details like small black text on a white background. Distance visual acuity is typically assessed by eye care professionals using letter acuity charts for viewing distances equivalent to 20 ft. Near acuity refers to visual acuity measured at a viewing distance of approximately 12–16 inches. The ability to see near objects clearly relies on accommodation or changes in the shape of the lens to bring the image into focus on the retina. However, the range of accommodation decreases with age as the lens in the eye hardens and becomes less malleable, reducing the clarity of objects positioned closer to the observer. Consequently, text and icons appearing on displays positioned more proximal to the driver, such as the dashboard, may appear blurry to older adults despite appearing in focus for a younger driver.

Contrast sensitivity refers to the ability to discriminate subtle differences in shading between say a white background and a target that is a light shade of gray. Age-related changes in acuity and contrast are relevant to the design of visual DMS warnings, alerts or cautions and are particularly important to ensure said stimuli are detectable and legible for older adults. For example, the visual presentation of DMS warnings pertaining to lane deviation or an alert about driver drowsiness may not be detected if it has low contrast and if it is detected it may not be legible if it is too small to resolve. Larger text and higher contrast will improve the legibility and visibility of the visual warning for all users and more robust to the effects of changing environmental conditions (e.g., bright sunlight, low illumination).

Older adults might also experience hazy or blurry vision due to cataracts that are more common with age. Cataracts are found in the lens of the eye and scatter light, reducing the contrast of visual scene while also increasing an individual's susceptibility to visual glare especially at nighttime and in the presence of on-coming vehicle headlights (Wood & Chaparro, 2011; Wood, Chaparro, Carberry, & Chu, 2010). Older driver are more likely to wear corrective lenses with bifocals that allow them to see near objects more clearly. Wearers of corrective lenses may assume head postures that impact reliability of a DMS. Also, research on eye tracking technology has shown that errors may occur when the user is wearing corrective lenses (Dahlberg, 2010). The DMS uses similar technology and may experience difficulties tracking the eyes of drivers wearing corrective lenses and hence assessing their attentional state.

Interactions With Hearing Changes

Older listeners often require sounds to be louder in order to be able to easily detect them. This is especially true in the presence of background noise, such as road and car noise. For younger adults, the recommended sound level when designing auditory displays is 70 dB, but this recommendation increases to 85–90 dB when designing for older adults (McLaughlin & Pak, 2020). Even if older adults do not have documented hearing loss, it may still be difficult for them to perceive some sounds common to speech, due to age related changes in the inner ear and reduced sensitivity to higher sound frequencies (McLaughlin & Pak, 2020). Therefore, it is important to consider the properties of auditory alarms to ensure their detection by older drivers, especially in the presence of background noise.

Auditory stimuli may be used in conjunction with redundant visual cues or haptic cues to alert the driver of their inattentiveness. General Motors' SuperCruise, a driver assistive technology feature, escalates its alert types if the driver fails to respond by assuming control of the vehicle or attending to the driving scene ahead. Upon first detection of inattentiveness, a green bar found on the steering wheel will begin to flash. If the driver does not respond, the bar will begin to flash red and is accompanied by auditory beeps or Safety Alert Seat vibrations. If no response is detected after the first two series of alerts, a voice will prompt the driver to take over control of the vehicle, and if nothing is done the vehicle will begin to slow down and brake while contacting an Onstar advisor to advise them of an emergency (How to use super cruise, n.d.). This multimodal approach to DMS warnings has the potential to help older drivers better detect messages, however due to changes in hearing, vision, and sensation normal to aging, older adults may still have difficulty perceiving these warnings.

Interactions With Changes in Cognition

The research literature documents important changes in attentional abilities with age; particularly, changes in divided and selective attention. Divided attention concerns the ability to attend to multiple concurrent stimuli, while selective attention concerns the ability to detect a target in the presence of distractors or other forms of visual clutter (Ball et al., 1993; Wood et al., 2006). The speed and performance of visual search (i.e., percent detection) declines with age (Karthaus & Falkenstein, 2016). These changes may impact the driver's ability to manage multiple tasks (Salthouse et al., 1984; Chaparro, Wood & Carberry, 2005), such as responding to navigational instructions, answering incoming calls or detecting the presence of an alert or warning under demanding driving conditions. Older drivers may be disadvantaged if the DMS warnings require them to shift attention away from the road to search for the warning and respond to it.

Interactions With Musculoskeletal Changes

Response time is affected by age, increasing approximately 25% by age 65 (McLaughlin & Pak, 2020). Additionally, older drivers may experience restricted range of motion including decrease of motion of the head and neck, which limits the area they can see and interact with objects (Isler et al., 1997). Arthritis can further restrict movement such as turning or manipulating objects (Yang & Coughlin, 2014; Chaparro et al., 1999) and may affect older adults' ability to respond promptly to a warning, or their ability to turn or press a button.

Other Interactions With Aging

The introduction and acceptance of the new technology by older adults must also to be considered. The learning styles of older adults and younger adults can differ, as younger adults have grown up utilizing and adapting to new technological advancements. Accommodating learning styles or preferences should be reflected in the creation of learning materials and user manuals to facilitate learning, use, and adoption of safety features that might reduce their crash risk. Older adults take longer to learn how to properly use advanced features such as a DMS compared to younger adults (Yang & Coughlin 2014; AAA Foundation for Traffic Safety, 2008; Caird, 2004). Also, the lack of intuitiveness of these features and perceived utility may dissuade older adults from using the technologies. Some of the best sources for learning about the operation of the vehicle's features, such as the cars owner's manual, are seldomly consulted by drivers (Mersinger & Chaparro, 2022) and do not support the learning styles that are preferred by older users.

Positive Interactions With Aging

The DMS has the potential to reduce crashes due to driver distraction or inattention. In the case of older drivers, it may detect unsafe driving behaviors before they become problematic, allowing them to maintain their transportation independence and reduce social isolation. Social isolation is associated with significant negative health consequences and reduces quality of life in older populations (Newman-Norlund, et al., 2022). In the case of self-driving vehicles, a DMS may be capable of taking over the car if an older adult experiences health related difficulties while driving. In the near future cars may be equipped with real-time in-car health monitoring systems that can detect health abnormalities, such as a stroke, using cushion and heart rate sensors embedded in the car seat (Park et al., 2019). In this scenario, the DMS may be able to switch the car control to an autonomous driving mode and safely maneuver the vehicle to a safe parking location.

CONCLUSION

With aging comes many physical, cognitive, and musculoskeletal changes. These changes may affect a broad range of daily activities including driving and interacting with systems in a vehicle. The ubiquity of DMS equipped vehicles highlights the importance of considering older drivers when designing these systems. Poor design may result in frequent and unnecessary alerts. To date, little research has been done to examine the interactions between DMS and older users.

FUTURE RESEARCH

This paper reviewed how the design of a DMS may interact with common age-related changes. Future research should assess how DMS might be designed to improve accessibility for older drivers who experience a diverse set of physical, motor, cognitive, and sensory changes. Researchers should examine whether a DMS can assess driver attention reliably, and how interface design considerations can improve user interaction with these systems. Future research should assess how the use of these systems impact older driver behavior, specifically whether drivers with DMS equipped vehicles are in fact more attentive. Finally, it is important to assess whether older adults will adopt this technology. Research has shown that older adults are less likely to adopt new technology, due to both perceptions of competence in learning new technology, as well as perceptions of perceived value or change in quality of life (Berkowsky et al., 2018).

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