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Article

Use and Perceptions of Advanced Driver Assistance Systems by Older Drivers With and Without Age-Related Macular Degeneration

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Purpose: Advanced driver assistance systems (ADAS) have been reported to improve the safety of elderly and normally sighted drivers. The purpose of this study was to assess exposure to, perceived safety of, comfort level with, and interest in using ADAS among drivers with age-related macular degeneration (AMD).

Methods: Current drivers aged 60+ years were recruited at four US sites to complete a survey about ADAS and driving habits. Frequency of use and/or perceptions of eight ADAS were investigated. An avoidance score was generated using questions about difficult driving situations.

Results: The survey was completed by 166 participants (80 with AMD vs. 86 without). Participants with AMD had worse self-rated vision than those without (34% vs. 2% poor or fair rating), and drove fewer weekly miles (median [interquartile range [IQR] 30 [15 to 75] vs. 60 [30 to 121] miles, $P = 0.002$). Participants with AMD reported more avoidance of difficult driving situations ($P < 0.001$). There was no difference in the number of ADAS used by AMD status (median [IQR for AMD = 2.5 [1 to 5] vs. 3 [2 to 4] without, $P = 0.87$). Greater reported number of ADAS used was associated with less avoidance of difficult situations ($P = 0.02$). The majority perceived improved safety with most ADAS.

Conclusions: Many drivers with AMD utilize common ADAS, which subjectively improve their road safety and may help to reduce self-imposed restrictions for difficult situations and mileage.

Translational Relevance: Drivers with AMD are adopting readily available ADAS, for which they reported potential benefits, such as safety and less restrictive driving.

Introduction

Older drivers are the fastest growing segment of the driving population. According to the Federal Highway Administration, nearly 1 in 5 drivers was aged 65 years or older in 2016, and the number of drivers 85 years and older increased by over 150,000 people between 2015 and 2016.[1] Although older drivers drive fewer miles than their younger counterparts, the number of miles driven by people aged 70 years and older is increasing.[2] Enabling older people to continue to drive

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for as long as possible is important for maintaining their overall quality of life. Driving cessation is strongly associated with a loss of independence, increased social isolation, and depression.[3–5] However, safety also needs to be considered. The increasing prevalence of age-related vision impairment,[6] as well as declines in physical and cognitive capacities,[7,8] may put older drivers at increased risk for unsafe driving, endangering both themselves and other road users.

In the United States, many jurisdictions allow people with reduced visual acuity of varying degrees (e.g. 20/40 or worse) to legally drive with a restricted license that includes limitations, such as daylight only driving, no highway driving, or driving only within a limited distance from home.[9] Thus, it is possible for older drivers with age-related vision impairment, such as individuals with age-related macular degeneration (AMD), to continue driving even when visual acuity no longer meets the criteria for an unrestricted license. However, a recent on-road study[10] reported that drivers with early and intermediate AMD (visual acuity 20/40 or better) were rated as less safe, made more errors in observation, lane keeping and gap selection, and made more critical errors than age-matched drivers without ocular disease. Furthermore, in driving simulator studies, participants with AMD had delayed responses to stop signs and traffic lights,[11] and to potential hazards[12,13] when compared with normally sighted, age-matched drivers. In addition, drivers with AMD have been reported to make more lane crossings[11] and tend to be slower to respond to changes in the speed of a lead car[14] in simulated driving; although one study found no differences between AMD and control drivers for these measures.[15]

It is well documented that many drivers with AMD self-restrict their driving by reducing their weekly mileage and avoid driving situations that are challenging, such as driving at night, in adverse weather conditions, and on high traffic roads.[16–19] In addition, drivers with AMD drive more slowly than their age-matched counterparts without ocular disease in simulated driving.[11,14,15] Both self-restriction and slower driving may help drivers with AMD to partly compensate for their vision loss. Nevertheless, data from studies evaluating driving performance on the road[10] and in driving simulators[11,12,15] suggests that drivers with AMD may be at higher risk for collisions than older drivers without vision impairment.

Advanced driver assistance systems (ADAS) have been developed with the goal of improving driver safety and are becoming widely available in many new cars. In 2013, only 0.2% of new cars had forward collision warning, 0.2% had lane departure warning, 1.6% had automatic emergency braking, and 3.2% had blind spot warning, compared to 38.3%, 30.1%, 42.0%, and 30.70%, respectively, in 2018.[20] This dramatic increase in the availability of ADAS may in part reflect the fact that, in September 2016, the National Highway Traffic Safety Administration and Insurance Institute for Highway Safety announced an agreement in principle with automakers to make a number of ADAS standard on passenger vehicles.[21] In general, it is anticipated that ADAS may improve driver safety by decreasing crash risk. In one report, rear end crashes were decreased by 23% with forward collision warning and by 39% with automatic braking, and even crashes that were not fully avoided by the ADAS system had reduced injuries because the ADAS reduced the speed at impact.[21] Based on a retrospective analysis of crash reports from 2011 to 2015, Wang[20] estimated that ADAS crash avoidance technologies could prevent 62% of all crashes (with forward collision prevention, lane keeping assistance, and blind spot warning preventing the greatest numbers of crashes) and 62% of all traffic deaths (with lane keeping assistance and pedestrian automatic braking preventing the greatest numbers of deaths).

Potentially, ADAS technologies could help mitigate collision risk for older drivers with AMD, especially in situations where they are slow to respond to a potential hazard or if they veer out of their lane. Although there are many studies on the use of ADAS by normally sighted drivers and by older drivers,[22–26] to our knowledge, there are no data on the use of crash avoidance ADAS by drivers with vision impairment, and we are aware of only one study on the use of GPS by drivers with vision impairment.[27] To advance our knowledge of the use of ADAS by drivers with AMD, we administered in the present study a questionnaire to current drivers with AMD and a similarly aged control group without a diagnosis of AMD. We quantified exposure to and knowledge of common ADAS technologies, as well as participants' experiences with the various ADAS in their vehicles. We expected that the two groups would not differ in exposure to and usage of ADAS. However, we anticipated that participants with AMD would perceive a greater benefit for improved safety from the ADAS as compared with their peers without AMD. We also anticipated that the AMD participants might report greater difficulties in using ADAS technologies compared to the non-AMD group, especially for those ADAS with visual displays or visual warnings. We further predicted that AMD participants who reported greater usage of ADAS would have less restricted driving habits. In addition, we inquired about participants' trust in new technology in general and tested the hypothesis that increased trust would be associated with greater ADAS usage. Collectively, these data will provide support for whether drivers with AMD are adopting, embracing, and/or potentially benefitting from the newer ADAS technologies that are readily available in new vehicles today.

Methods

Participants and Study Sites

Participants aged 60 years and older were recruited from the clinical practices and/or existing research databases at the following sites in the United States: The Ohio State University; The University of California, Los Angeles Stein Eye Institute; New England College of Optometry; and the Envision Research Institute. Participants self-identified as having AMD or having no known eye disease; additionally, the ocular disease status of participants was confirmed by review of their clinical examination record at three of the four sites. Those diagnosed with eye disease other than AMD were excluded. Eligible participants were required to possess a valid driver's license and indicate they had driven a car in the previous 2 months. We excluded non-English speakers and those with hearing impairment that prohibited verbal completion of the survey.

To confirm that participants did not have a significant cognitive impairment, five questions were asked to assess their orientation, place, and person (i.e. town/city, US state in which they reside, the current month and year, and their name). Correct responses to all of these questions were required to continue in the study. Informed consent was obtained for all participants. The study was approved by the Ohio State University Institutional Review Board (IRB), which served as the single IRB with approved reliance agreements from the other institutions' IRBs for this multisite research study. The study conformed to the tenets of the Declaration of Helsinki.

Survey and Administration

Participants self-rated their vision on a five-point scale (excellent, very good, good, fair, and poor), as well as reported if any vision problems made driving more stressful. Additional information about other comorbidities that might affect driving was collected; specifically, subjects self-reported on any difficulty with hearing, turning the head or neck, moving the feet or pressing pedals, and/or remembering things. The participants responded to a single item about their level of trust in new vehicle technology. Participants also self-reported the number of miles they drove in the past week, as well as on how many days they normally drive. They completed a series of 11 questions about difficult driving situations and conditions, including avoidance of: freeways and interstate highways, cities, peak-hour traffic, high traffic roads, left turns across oncoming traffic, roundabouts, long distance driving, night driving, bad weather, bright sunny weather, and driving alone. An avoidance scale was created from the 11 questions as a summary measure of avoidance of difficult situations. A dichotomous response structure (avoids for any reason [visual or otherwise] versus does not avoid) was applied to the data from each question. Participants were asked about their opinion of road safety where they drive regularly.

To assess the impact that the coronavirus disease 2019 (COVID-19) pandemic may have had on participants' driving habits and perception of road safety, the survey also included questions about changes in driving behavior, driving habits, and perceptions of road safety before the COVID-19 pandemic began in the United States in March 2020.

Each participant completed survey items about the vehicle they drove, including make, model, and year. They also answered questions about their experience with and perception of various ADAS. The ADAS assessed in this study included: forward collision warning, forward collision avoidance, blind spot warning, lane departure warning, rearview camera, cruise control (sometimes classified simply as a driver assistance system (DAS), rather than ADAS), adaptive cruise control, and Global Positioning Systems (GPS) navigation system. During the survey administration, participants were given a brief description about each ADAS, including what it was and what it did, and then were asked if that system was present in their current vehicle. For each ADAS that a participant reported they had in their vehicle, survey questions were completed about frequency of use and perception of improvement in their driving safety associated with the system. If participants did not have a particular ADAS, they completed survey questions about their knowledge of the ADAS and its predicted benefit(s) to their driving behavior and safety. A general schematic of the branching logic included in the survey can be seen in the Figure.

The survey was administered verbally, either over the telephone or in the clinical setting, by the coauthors or trained research assistants at their institutions. Participant responses were recorded and stored online using the Research Electronic Data Capture (REDCap) system. Study data were collected and managed using REDCap electronic data capture tools hosted at The Ohio State University.[28,29] REDCap

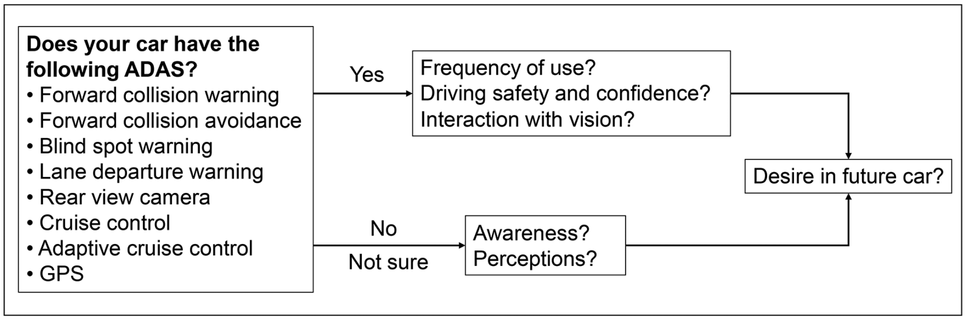

Figure. Branching design for main constructs assessed with survey executed in REDCap.

is a secure, web-based software platform designed to support data capture for research studies, providing (1) an intuitive interface for validated data capture; (2) audit trails for tracking data manipulation and export procedures; (3) automated export procedures for seamless data downloads to common statistical packages; and (4) procedures for data integration and interoperability with external sources. This allowed for automatic branching of the survey items as described above.

Data Analyses

Descriptive statistics were used to summarize participant characteristics and frequency of ADAS use, as well as perceptions of usefulness of various ADAS for nonusers. *T*-tests, median tests, and chi-square tests were used to compare participant characteristics, ADAS use, and perceptions of drivers with AMD to those of drivers without AMD. Spearman correlation and Kruskal-Wallis tests were used to assess relationships among participant characteristics, avoidance scores, and ADAS use. Rasch analysis[30] of the responses to the 11 questions on avoidance of difficult driving situations was used to calculate a summary avoidance score for all participants. Responses were treated as dichotomous (reports avoiding the driving situation versus does not report avoiding). The infit mean square fit statistic was used to assess the fit of each of the 11 items to the Rasch model, with values between 0.7 and 1.3 considered acceptable.[31,32] We assessed the unidimensionality of the scale using a principal component analysis of model residuals, with an eigenvalue of the first contrast of less than 2.0 considered evidence of unidimensionality.[31] Rasch analysis was performed using Winsteps version 4.5.1. All statistical testing was performed using IBM SPSS Statistics version 25.

Results

Participants' Characteristics

The survey was completed by 166 participants (80 with AMD and 86 without) between July 15, 2020, and February 8, 2021. All participants were licensed drivers who reported that they had operated a vehicle in the past 2 months. Participants with AMD were slightly older (mean age = 75 years; SD = 10) when compared to participants without AMD (mean age = 72 years; SD = 7; $P < 0.001$). The proportion of female participants was similar between groups (51% for AMD and 54% for non-AMD). Regarding comorbidities, 10 subjects reported hearing difficulty (8 with AMD and 2 without), 6 reported difficulty turning their head or neck (3 with AMD and 3 without), one reported trouble remembering things (one with AMD), and none reported problems with foot movement.

Participants with AMD had worse self-rated vision than those without AMD, with 34% of participants describing their vision as poor or fair in the AMD group versus only 2% of those in the non-AMD group ($P < 0.001$). A greater proportion ($P < 0.001$) of participants with AMD reported vision problems that affected their driving (90%) than those without AMD (47%). Similarly, a greater proportion ($P < 0.001$) of participants with AMD indicated that their vision problems made driving more stressful (60%) than those without AMD (24%). Those with AMD also reported driving significantly fewer miles per week than those without AMD (median [interquartile range] for AMD = 30 [15 to 75] miles, and for non-AMD = 60 [30 to 121] miles, $P = 0.002$ for a test of whether the median mileage was the same across groups).

Both groups of participants reported they drove more miles prior to the start of the COVID-19 pandemic (52.5 [27 to 150] pre-COVID-19 for people with AMD and 100 [64 to 200] pre-COVID-19 for people without AMD); however, 95% of participants reported that they did not perceive a difference in road safety due to the pandemic. Participants overwhelmingly (96%) reported that the roads where they drove regularly were generally safe, and there was no difference in opinion of road safety according to AMD status ($P = 0.71$). The median vehicle model year was 2014 for participants with AMD and 2015 for participants without AMD.

The majority of participants reported that they drove mostly in urban environments, defined as having a population >20,000 people, which was the case for two thirds of non-AMD participants and 56% of those with AMD. There was no significant difference in the driving environment in which participants drove the most by AMD status ($P = 0.09$).

Driving Avoidance Behavior

Greater proportions of participants with AMD reported avoidance of 11 potentially difficult driving situations when compared to those without AMD, as shown in Table 1. Rasch analysis of the questions on avoidance of difficult driving situations revealed that all 11 items had acceptable infit statistics ranging from 0.84 to 1.18, indicating fit to the Rasch model.[31] The percentage of total variance explained by the measures is 41.3, and the eigenvalue of the first contrast of the principal component analysis was 1.79, indicating the avoidance scale was unidimensional.[31] Participants with AMD had significantly higher avoidance scores than those without AMD ($P < 0.001$), and those with AMD who reported worse vision had higher avoidance scores ($P < 0.001$). Avoidance scores were inversely related to typical weekly mileage driven across all participants, with a significant association between more avoidance of difficult driving situations and reduced weekly mileage (Spearman rho = −0.370, $P < 0.001$).

Use of ADAS

Table 2 displays the percentage of participants who reported that they currently use various ADAS according to AMD status. Participants with AMD reported using a median (interquartile range) of 2.5 (1 to 5) of the ADAS that we surveyed, compared to 3 (2 to 4) for those without AMD ($P = 0.220$). The ADAS most commonly used by both groups were GPS, cruise control, and rearview camera. Significantly fewer people with AMD reported using GPS and cruise control than those without AMD (GPS 66% with AMD versus 80% without, $P = 0.02$; cruise control 56% with AMD versus 67% without, $P = 0.002$).

Factors Associated With ADAS Usage

A greater reported number of ADAS used was associated with less avoidance of difficult situations and conditions (Spearman rho = −0.180, $P = 0.02$) across all participants. Sixty-nine percent of all participants reported being either “comfortable” or “very comfortable” trusting new vehicle technology. Thirteen percent of participants with AMD reported being either “uneasy” or “not at all comfortable” with trusting new technology, versus 20% of those without AMD. There was no significant difference in opinions on trust in new vehicle technology by AMD status ($P = 0.45$). Increased trust in technology was significantly associated with greater number of ADAS used across all participants ($P = 0.003$). There was no differ-

Table 1. Avoidance Behavior for Various Difficult Driving Situations

Driving Situation	AMD % Avoid Overall	AMD % Avoid Due to Vision	AMD % Avoid Unrelated to Vision	Non-AMD % Avoid Overall
Night driving	68.8	67.5	1.3	31.4
Bad weather	53.7	25.0	28.7	39.6
Peak hour traffic	48.8	18.8	30.0	44.2
High traffic roads	43.0	13.9	29.1	27.9
Long distances	41.3	21.3	20.0	15.2
Highways	31.3	17.5	13.8	9.3
Cities	28.8	15.0	13.8	5.8
Rotary	20.0	10.0	10.0	8.2
Left turns	17.5	15.0	2.5	8.1
Bright sun	13.8	13.8	0.0	2.4
Driving alone	2.6	1.3	1.3	0.0

Table 2. Percent of Drivers Reporting Both Having and Using Various ADAS by AMD Status

ADAS	AMD % Have And Use	AMD % Have and Do Not Use	Non-AMD % Have and Use	Non-AMD % Have and Do Not Use
GPS*	66.3	5.0	80.2	5.8
Cruise control*	56.3	41.3	79.1	19.8
Rear view camera	55.0	2.5	67.4	0
Blind spot warning	38.8	0	36.0	0
Lane departure warning	28.7	1.3	22.1	3.5
Forward collision warning	25.0	1.3	19.8	0
Adaptive cruise control	17.5	8.8	7.0	9.3
Forward collision avoidance	16.3	3.8	11.6	1.2

Significantly different ($P < 0.05$) proportions of having and using between drivers with and without AMD are denoted with an asterisk (*).

ence in the number of ADAS reported to be used by gender ($P = 0.12$) or self-rating of vision ($P = 0.12$), but there was an inverse correlation between age and number of ADAS used (Spearman rho = −0.202, $P = 0.01$).

Safety Perceptions of ADAS by Current Users

Among participants who reported that they have ADAS in their vehicles, a majority believed the systems made them safer, with the exceptions of cruise control and adaptive cruise control, which had lower reported rates (40–55%) of being helpful with safety, when compared to other ADAS for which perceived safety was improved in 58–94% of participants, see Table 3. The ADAS with the greatest proportion of participants who perceived a safety improvement were blind spot warning (94%) and rearview camera (90%). There were no statistically significant differences in the distribution of opinions of current ADAS users regarding whether the systems make them safer by AMD status. The percentage of ADAS users with AMD who reported that various ADAS "helped compensate for their vision problems," ranged from 8% for cruise control to 55% for blind spot warning. Among ADAS users with AMD, there were no systems for which more than 10% of respondents reported that their vision made the system difficult to use.

Perceptions on ADAS From Current Nonusers

Opinions on various ADAS from drivers with AMD who did not have them in their current vehicle are shown in Table 4. For the less common ADAS, most drivers with AMD who did not have them believed their safety would be improved by: blind spot warning (84%), forward collision warning (70%), lane departure warning (67%), adaptive cruise control (57%), and forward collision avoidance (53%). Drivers with AMD generally felt that ADAS would make them safer, although fewer reported that the various ADAS systems would "help compensate for their vision problems." The majority reported a willingness to buy many of the systems in a new car, particularly those with perceived safety benefits, such as blind spot warning and rear camera.

Table 3. Percent of Current ADAS Users Who Reported that the Systems Improve Their Driving Safety by AMD Status

ADAS	% of AMD Drivers Who Feel it Improves Safety	% of non-AMD Drivers Who Feel it Improves Safety
Blind spot warning	93.5	93.5
Rearview camera	89.4	89.7
Lane departure warning	87.5	65.2
Forward collision warning	78.3	66.7
Forward collision avoidance	75.0	58.3
GPS	73.2	74.3
Cruise control	40.3	54.7
Adaptive cruise control	45.5	41.2

Table 4. Opinions of Drivers With AMD Who Do Not Have Various ADAS

ADAS	% of AMD Drivers Without ADAS Who Would Use It	% of AMD Drivers Without ADAS Who Feel it Would Improve Safety	% of AMD Drivers Without ADAS Who Feel it Would Compensate for Vision Problems	% of AMD Drivers Without ADAS Who Would Buy in New Car	% of AMD Drivers Without ADAS Who Would Not Buy But Would Take for Free
Blind spot warning	93.9	83.7	53.1	82.3	87.5
Forward collision warning	82.5	70.2	36.8	60.0	58.3
Rear view camera	73.5	76.5	38.2	88.5	28.6
Lane departure warning	71.4	66.7	34.5	71.8	58.8
Forward collision avoidance	64.1	53.1	34.9	54.4	54.5
Adaptive cruise control	57.9	57.1	24.6	46.2	38.2
GPS	54.5	54.5	45.5	64.1	65.0

Cruise control is not shown, as all but two drivers reported their vehicle had cruise control.

Discussion

In this survey study, many drivers with AMD reported utilizing commonly available ADAS, which subjectively improved road safety. For the majority of ADAS, usage rates did not differ between drivers with and without AMD. The two exceptions were cruise control and GPS, which were less likely to be used by drivers with AMD, possibly because they were more likely to avoid highway driving and driving in unfamiliar areas than the drivers without AMD. A large proportion of our survey participants with AMD indicated that they perceived safety benefits from a variety of ADAS that are becoming more common, such as rearview camera and blind spot warning. A majority of participants with AMD who currently used ADAS in their vehicles reported driving safety benefits for all systems. Cruise control was the system mostly likely to be unused by drivers with and without AMD even though it was present in the majority of cars. Most of those with AMD who did not have other various ADAS also thought that safety could be improved with these systems. The majority also indicated willingness to buy them in a new car. There was no difference in the perceived safety benefit of ADAS when comparing current ADAS users who did or did not have AMD. These findings suggest that people with AMD are receptive to using ADAS for potentially enhanced safety while driving.

It is not fully clear what barriers exist to obtaining ADAS for drivers with AMD who do not have the systems but report interest in their use. Certainly, one potential barrier is cost, as a number of the participants reported they were not interested in purchasing the systems in new cars but would accept them if they were free (Table 4). Other barriers to obtaining ADAS might include unfamiliarity with the systems, perception that the systems make things more complicated or are distracting, or hesitancy to give up vehicle control to automated systems. Further investigation into the reasons for non-adoption would be beneficial to help overcome the perceived barriers.

Our survey findings for the avoidance of difficult driving situations are in agreement with previous research and add to the body of knowledge that drivers with AMD exhibit more avoidance of difficult situations, especially driving at night, and lower weekly mileage than those without AMD.[11,16,17,19,33] A novel finding from our survey was that the use of an increased number of ADAS was associated with subjectively reduced avoidance of difficult driving situations among older drivers with AMD. There could be potentially important, positive effects of using multiple ADAS to enable less restrictive driving behaviors, which were more commonly reported for people with AMD and were related to self-reported vision loss. In the future, it would be valuable to elucidate which ADAS or combination of ADAS can help with different types of driving environments that are challenging during longitudinal, observational studies of driving habits. For instance, whereas some functions of ADAS should prove useful in all environments (avoiding a suddenly stopped vehicle ahead or a vehicle in a driver's blind spot during a lane change), it is possible that at least some ADAS are even more valuable in unfamiliar driving environments. Additionally, although only drivers with central vision loss were surveyed for the present study, perceptions of ADAS from drivers with peripheral vision loss (and effects on driving performance) should also be studied further.

Our survey did not inquire about ADAS to help with night vision because those systems are currently infrequently found in vehicles, and we did not anticipate that a meaningful number of participants would be able to share their experience. This would be an important area for future study once they are more common because people with AMD avoid night driving due to reduced scotopic vision.[34] Inherent potential limitations of our survey study design are the potential for recall bias and convenience sampling from our institutions. However, the strengths of our survey study include survey responses from people from different regions of the United States, and both rural and urban areas.

As with any preliminary study involving a survey to obtain user feedback and experiences, additional work will be needed to objectively assess driving performance with ADAS. Our study provides support for several hypotheses related to the use of ADAS by people with AMD to improve driving safety and reduce driving avoidance. There were several interesting and unanticipated findings from our survey that suggest the relationship between vision and ADAS is complex. These included that participants with AMD did not tend to report that their vision made ADAS difficult to use, given that some ADAS use small, detailed visual signals or controls. The fact that participants with AMD in this study were all active, licensed drivers suggests that they have relatively good vision, even though we hypothesized that some drivers with AMD who have worse vision might report more visual difficulty with the screen displays or visual warnings in ADAS. Other potential explanations for the apparent lack of visual difficulty with ADAS are that participants may not make attempts to adjust the display settings of their systems or they rely primarily on the audio indicator features of the ADAS. For all ADAS except blind spot warning, another interesting finding was that only a minority of all participants with AMD who either did or did not use ADAS thought they did or would help compensate for vision problems specifically, even if they perceived an improvement for their driving safety with these systems. Future studies should confirm whether these opinions of AMD participants reflect real-world experiences with ADAS visual displays by comparing their performance and utilization with measures of participants' visual function with standardized, validated tests. These data provide justification to pursue future studies to determine the usability and potential benefits of ADAS for drivers with AMD. Specifically, it would be valuable to assess whether ADAS can help with difficult driving situations that are commonly avoided by those with AMD. Longitudinally, another aspect to evaluate is whether increased automation might lead to complacency and worse situational awareness,[35] which may compromise safety in situations when driver reactions are still required to avoid collisions.

It is important to evaluate the potential of ADAS to improve safety in drivers with AMD because they have been previously rated as less safe than similarly aged, normally sighted drivers.[10] Various types of ADAS may help to compensate for the delayed hazard responses that have been previously documented in drivers with AMD.[12] On-road assessments of drivers with AMD revealed common errors related to blind spots and observation of surroundings,[10] which could be potentially improved with the blind spot warning and rearview camera available as ADAS. Among our survey respondents with AMD, there was a trend for greater acceptance of those types of warning systems than other ADAS that perform evasive maneuvers, such as forward collision avoidance and adaptive cruise control. Our survey respondents who reported greater trust in technology tended to use a greater number of ADAS, which was similar among those with or without AMD. Thus, efforts to increase trust in ADAS technology by older adults via educational programs and/or demonstrations may be valuable to increase their use.

Conclusions

ADAS are becoming widely available in many new cars. Although these systems improve the driving safety of elderly and normally sighted drivers, the perceived improvements to safety noted by people with AMD in our work provides support to conduct further research to objectively assess whether road safety and driving performance improves in drivers with AMD as a result of these systems. The use of ADAS may allow people with AMD to drive more and in challenging situations, which would be important given their self-restricted driving habits and avoidance of difficult driving conditions.

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References

1. Older Drivers Set Record For Second Year: U.S. Department of Transportation; 2017. Available from: https://www.transportation.gov/briefing-room/fhwa2017.
2. Older drivers: Insurance Institute for Highway Safety, Highway Loss Data Institute; 2021. Available from: https://www.iihs.org/topics/older-drivers.
3. Chihuri S, Mielenz TJ, DiMaggio CJ, et al. Driving Cessation and Health Outcomes in Older Adults. *J Am Geriatr Soc*. 2016;64(2):332–341.
4. Fonda SJ, Wallace RB, Herzog AR. Changes in driving patterns and worsening depressive symptoms among older adults. *J Gerontol B Psychol Sci Soc Sci*. 2001;56(6):S343–S351.
5. Ragland DR, Satariano WA, MacLeod KE. Driving cessation and increased depressive symptoms. *J Gerontol A Biol Sci Med Sci*. 2005;60(3):399–403.
6. Chan T, Friedman DS, Bradley C, et al. Estimates of Incidence and Prevalence of Visual Impairment, Low Vision, and Blindness in the United States. *JAMA Ophthalmol*. 2018;136(1):12–19.
7. Ehrlich JR, Swenor BK, Zhou Y, et al. The Longitudinal Association of Vision Impairment with Transitions to Cognitive Impairment and Dementia: Findings from The Aging, Demographics and Memory Study. *J Gerontol A Biol Sci Med Sci*. 2021;76:2187–2193.
8. Zheng DD, Swenor BK, Christ SL, et al. Longitudinal Associations Between Visual Impairment and Cognitive Functioning: The Salisbury Eye Evaluation Study. *JAMA Ophthalmol*. 2018;136(9):989–995.
9. Peli EP. *Driving with Confidence: A Practical Guide to Driving with Low Vision*. Hackensack, NJ: World Scientific Publishing Company; 2002.
10. Wood JM, Black AA, Mallon K, et al. Effects of Age-Related Macular Degeneration on Driving Performance. *Invest Ophthalmol Vis Sci*. 2018;59(1):273–279.
11. Szlyk JP, Pizzimenti CE, Fishman GA, et al. A comparison of driving in older subjects with and without age-related macular degeneration. *Arch Ophthalmol*. 1995;113(8):1033–1040.
12. Bronstad PM, Bowers AR, Albu A, et al. Driving with central field loss I: effect of central scotomas on responses to hazards. *JAMA Ophthalmol*. 2013;131(3):303–309.
13. Bronstad PM, Albu A, Bowers AR, et al. Driving with Central Visual Field Loss II: How Scotomas above or below the Preferred Retinal Locus (PRL) Affect Hazard Detection in a Driving Simulator. *PLoS One*. 2015;10(9):e0136517.
14. Coeckelbergh TR, Brouwer WH, Cornelissen FW, et al. The effect of visual field defects on driving performance: a driving simulator study. *Arch Ophthalmol*. 2002;120(11):1509–1516.
15. Bronstad PM, Albu A, Goldstein R, et al. Driving with central field loss III: vehicle control. *Clin Exp Optom*. 2016;99(5):435–440.
16. Ball K, Owsley C, Stalvey B, et al. Driving avoidance and functional impairment in older drivers. *Accid Anal Prev*. 1998;30(3):313–322.
17. Moore LW, Miller M. Driving strategies used by older adults with macular degeneration: assessing the risks. *Appl Nurs Res*. 2005;18(2):110–116.
18. Sengupta S, van Landingham SW, Solomon SD, et al. Driving habits in older patients with central vision loss. *Ophthalmology*. 2014;121(3):727–732.
19. DeCarlo DK, Scilley K, Wells J, et al. Driving habits and health-related quality of life in patients with age-related maculopathy. *Optom Vis Sci*. 2003;80(3):207–213.
20. Wang J-S. *Target Crash Population For Crash Avoidance Technologies in Passenger Vehicles*. Washington, DC: National Highway Traffic Safety Administration, 2019.
21. Status Report: Crashes Avoided: Insurance Institute for Highway Safety, Arlington, VA: Highway Loss Data Institute, 2016. Available at https://www.iihs.org.
22. Braitman KA, McCartt AT, Zuby DS, et al. Volvo and Infiniti drivers' experiences with select

crash avoidance technologies. *Traffic Inj Prev*. 2010;11(3):270–278.
23. Eby DW, Molnar LJ, Zhang L, et al. Use, perceptions, and benefits of automotive technologies among aging drivers. *Inj Epidemiol*. 2016;3(1): 28.
24. Eichelberger AH, McCartt AT. Volvo drivers' experiences with advanced crash avoidance and related technologies. *Traffic Inj Prev*. 2014;15(2): 187–195.
25. Eichelberger AH, McCartt AT. Toyota drivers' experiences with Dynamic Radar Cruise Control, Pre-Collision System, and Lane-Keeping Assist. *J Safety Res*. 2016;56:67–73.
26. Vrkljan BH, Polgar JM. Driving, navigation, and vehicular technology: experiences of older drivers and their co-pilots. *Traffic Inj Prev*. 2007;8(4):403–410.
27. Cucuras M, Chun R, Lee P, et al. GPS Usage in a Population of Low-Vision Drivers. *Semin Ophthalmol*. 2017;32(4):438–442.
28. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: Building an international community of software platform partners. *J Biomed Inform*. 2019;95:103208.
29. Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap)–a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42(2):377–381.
30. Rasch G. *Probabilistic models for some intelligence and achievement tests*. Copenhagen, Denmark: Danish Institute for Educational Research; 1960.
31. Linacre JM. *A User's Guide to Winsteps: Rasch-Model Computer Program*. 2002. Available at https://www.researchgate.net/publication/238169941_A_User's_Guide_to_Winsteps_Rasch-Model_Computer_Program.
32. Pesudovs K, Burr JM, Harley C, et al. The development, assessment, and selection of questionnaires. *Optom Vis Sci*. 2007;84(8):663–674.
33. Freeman EE, Munoz B, Turano KA, et al. Measures of visual function and their association with driving modification in older adults. *Invest Ophthalmol Vis Sci*. 2006;47(2):514–520.
34. Scilley K, Jackson GR, Cideciyan AV, et al. Early age-related maculopathy and self-reported visual difficulty in daily life. *Ophthalmology*. 2002;109(7):1235–1242.
35. Souders D, Charness N. Challenges of Older Drivers' Adoption of Advanced Driver Assistance Systems and Autonomous Vehicles. In: Zhou J, Salvendy G, eds. International Conference on Human Aspects for IT for the Aged Population. Toronto, Canada: Springer, 2016.

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