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Valuation of Active Blind Spot Detection Systems by Younger and Older Adults

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Abstract

Due to their disproportional representation in fatal crashes, younger and older drivers both stand to benefit from in-vehicle safety technologies, yet little is known about how they value such technologies, or their willingness to adopt them. The current study investigated older (aged 65 and greater; $N = 49$) and younger (ages 18-23; $N = 40$) adults' valuation of a blind spot monitor and asked if self-reported visual difficulties while driving predicted the amount participants were willing to pay for a particular system (BMW's Active Blind Spot Detection System) that was demonstrated using a short video. Large and small anchor values (\$250 and \$500, respectively) were used as between subjects manipulations to examine the effects of initial valuation, and participants proceeded through a short staircase procedure that offered them either the free installation of the system on their current vehicle or a monetary prize (\$25-\$950) that changed in value according to which option they had selected in the previous step of the staircase procedure. Willingness to use other advanced driver assistance systems (lane-departure warning, automatic lane centering, emergency braking, adaptive cruise control, and self-parking systems) was also analyzed, additionally controlling for prior familiarity of those systems. Results showed that increased age was associated with a higher valuation for the Active Blind Spot Detection System in both the large and small anchor value conditions controlling for income, gender, and technology self-efficacy. Older adults valued blind spot detection about twice as much (\$762) as younger adults (\$383) in the large anchor condition, though both groups' values were in the range for the current cost of an aftermarket system. Similarly, age was the most robust positive predictor of willingness to adopt other driving technologies, along with system familiarity. Difficulties with driving-related visual factors also positively predicting acceptance levels for adaptive cruise control and emergency braking systems. Results are discussed in comparison to older adults' willingness to pay for other home-based assistive technologies aimed at improving well-being and independence.

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Keywords

Advanced Driver Assistance Systems; Older Adults; Self-reported Vision; Technology Adoption; Valuation

1. INTRODUCTION

Intelligent vehicle technology (IVT), such as advanced driver assistance systems (ADAS), vehicle to vehicle communication (V2V), and fully autonomous vehicles (AV) has the potential to improve driver safety and promote more efficient use of roadway systems. Two age groups have the highest fatal crash risk: younger, particularly teen drivers, and older drivers, particularly those age 75+ years (Cerelli, 1998). Hence, it is important to consider willingness to adopt and use IVT at both ends of the age spectrum. Although we wish to compare both younger and older drivers with respect to acceptance of such technology, we note that older drivers whose cognitive and sensory abilities are on the decline, may have more to gain by accepting the type of assistance that IVT can provide than their younger counterparts whose cognitive and sensory abilities are at or near their peak. Furthermore, older drivers have accrued more driving experience and might be more successful in using the feedback given by the IVT than less-experienced younger drivers. Also, older drivers are more likely than teen drivers to have the financial resources to become early adopters of IVT.

Countries around the world are experiencing increasing licensure rates for drivers over the age of 65 (Sivak & Schoettle, 2012). With this increase, age-related sensory, cognitive, and physical declines that affect an individual's driving abilities become a societal challenge. On one hand, decreasing fitness to drive in an increasing proportion of licensed drivers could potentially lead to serious safety concerns on the road, while on the other, older adults' ability to drive their own personal vehicle is strongly linked to their sense of independence and self-reliance (Oxley & Whelan, 2008) and driving cessation has been shown to contribute to a range of poor health outcomes for older adults (e.g., Chihuri et al., 2015).

1.1 Aging and Lane Change Behavior

Older drivers report difficulty changing lanes (Chandraratna, Mitchell, & Stamatiadis, 2002) and report making fewer lane changes overall (Boyle, Dienstfrey, & Sothoron, 1998). Cantin, Lavallière, Simoneau, & Teasdale (2009) have found that older drivers had longer reaction times when driving on a straight road or approaching an intersection than younger drivers, with disproportionately longer reaction times than younger drivers in overtaking maneuvers, suggesting that more complex driving contexts such as overtaking maneuvers required relatively more cognitive resources for older drivers compared to younger drivers. Crash data have shown that older drivers are five times more likely than younger drivers to be cited for a failure to yield when merging or changing lanes, and are 63% more likely to have been changing lanes or merging prior to a crash than younger drivers (Chandraratna et al., 2002).

In a study of visual search behavior during self-initiated lane changes while driving on the highway, drivers in their 60's tended to make fewer left lane changes than younger drivers with no significant differences between age groups for lane changes to the right (Lavallière et al., 2011). Older drivers in this study were also significantly likely to neglect checking their left side mirror, rearview mirror and/or left blind spot than younger drivers, and only checked their left blind spot 23.9% of the time, while younger drivers checked it 53.3% of the time when making a left lane change.

Older drivers' visual scans when lane changing could be abbreviated due to workload involved with changing lanes. Reimer et al. (2013) observed fewer lane changes across age groups under secondary cognitive task load while driving on the highway. They additionally found that drivers in their 60's changed lanes less frequently than those in their 40's, though they did not statistically differ from drivers in their 20's.

1.2 Age-related Declines in Visual Attention & Peripheral Vision

Scenes that require a high degree of visual processing have been shown to reduce the functional field of view in older adults (Pak, Rogers, & Fisk, 2006). Older adults' speed and accuracy for identifying information in a scene decrease with greater amounts of clutter in that scene (Maltz & Shinar, 1999; McPhee, Scialfa, Dennis, Ho, & Caird, 2004), and this has been demonstrated in the driving task, with reports of perceptual narrowing in older drivers (Rogge et al., 2004).

Studies have shown that simulating constriction of the visual field adversely affects driving performance in both younger and older adults. Wood and Troutbeck (1992) restricted younger drivers' binocular visual field to 40 degrees and had them complete a driving course, resulting in increased difficulty in avoiding obstacles, maneuvering in tight spaces, and reduced accuracy in road positioning. Wood and Troutbeck (1995) simulated peripheral visual field restriction in older drivers (subjects still satisfied legal visual requirements for licensure), and found decrements in subjects' peripheral reaction times and peripheral awareness as well as increases in the time to complete the driving and maneuvering tasks.

Ball, Owsley, Sloane, Roenker, & Bruni (1993) found that older drivers with a reduction of 40% in their useful field of view (UFOV) scores were six times more likely to be involved in one or more crashes over the previous 5-year period than those with minimal or no UFOV reduction. If noticed by the individual, such spatial visual declines can lead that individual to limit their driving behavior in situations they deem difficult (West et al., 2003). Using advanced in-vehicle technologies to support older drivers' abilities behind the wheel has been proposed as one way of address such challenges (e.g., Eby et al., 2015). However, in order for these technologies to provide their potential benefit, they must first be accepted and adopted by older drivers.

1.3 Technology Adoption & Older Adults

The Technology Acceptance Model (TAM; Davis, 1989) is a widely used and extensively developed framework to explain technology adoption (Marangunić & Granid, 2015). Developed to explain user acceptance of information technology, it originally consisted of two factors: Perceived usefulness (i.e., the use of a new technology will enhance a person's

job performance) and perceived ease of use (i.e., the use of a new technology will be relatively free of effort). The Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh, Morris, Davis, & Davis, 2003) extends TAM and adds social influence as a determinant of behavioral intent to use a technology. UTAUT itself has been extended to ADAS (Adell, 2010). Though Adell's (2010) study was low in explanatory power, she found that effort expectancy was not significantly related to behavioral intent to use the collision warning-like ADAS proposed in the study. This suggests that older adults, who tend to shy away from technology that requires too much effort to use (Mitzner et al., 2010), might be attracted to ADAS that passively provide them benefits (e.g., warnings) after they are activated.

Older adults generally have less familiarity with new technologies than younger adults (e.g., Czaja et al., 2006), but are generally aware of, and receptive to new technologies they deem useful (Demiris et al., 2004). This is particularly true of technologies that provide clear benefits to their current lifestyle, and diminishes if they cannot anticipate the advantages of using a particular technology (Melenhorst, Rogers, & Caylor, 2001).

1.3.1 Valuation of Technology that Supports Independence—One could reasonably argue that older drivers would be particularly receptive to ADAS that might help them maintain their ability to drive their own personal vehicle safely, and thus maintain their independence. Quality of Life Technologies (QoLTs) are similarly aimed at helping assist the independent functioning of adults with disabilities, and end users' willingness to pay for these technologies have been studied. Schulz et al. (2014) investigated baby boomers' (age 45-64) and older adults' (aged 65+) willingness to pay for QoLTs (kitchen and personal care technologies specifically), and found that perceived future need for help in the kitchen or with personal care was consistently related to participants' willingness to pay for QoLTs that support these activities. All of the participants that reported one or more impairment with activities of daily life (ADL) were willing to pay *something* for these technologies (\$40.30/month on average for kitchen tasks and \$45/month for personal care tasks, \$25/month median for both). Schulz and colleagues also found, contrary to their predictions, that age and attitudes toward technology were not significantly related to willingness to pay for these QoLTs. Older respondents were less technologically averse than the authors expected, and positive general attitudes toward technology were not associated with a greater willingness to pay for QoLTs.

In this study, we investigate whether age or self-reported visual difficulties affect adults' valuation of a blind spot monitor system. Self-reported visual difficulties and their relation to participants' willingness to use other types of ADAS are also analyzed. Hypotheses are as follows:

H1: Drivers with greater self-reported vision-driving issues will value the ABSD system more than drivers that report fewer vision-driving issues.

H2: Willingness to use other ADAS will be positively related to self-reported vision-driving issues.

2. METHODS

2.1 Participants

Eighty-nine individuals completed the computer-based questionnaire in a laboratory-based environment. The sample included 40 younger adults ($M_{age} = 19.28$, $SD = 1.38$, $range = 18-23$; 27 females, 67.5%), majority Caucasian (57.5% Caucasian, 15% Black/African American, 17.5% Hispanic/Latino), median income of “less than \$10,000”, and currently enrolled in college courses. The sample also included 49 older adults ($M_{age} = 71.92$, $SD = 4.83$, $range = 65-90$; 28 females, 57.1%), primarily Caucasian (89.8%), with a median income of “\$40,000-\$59,999”, and median education of “Bachelor's degree”. When asked if they generally find new technology easy to use, younger adults ($M = 4.35$, $SD = 0.74$) responded with significantly greater agreement ($t(87) = 4.81$, $p < .001$) than older adults ($M = 3.49$, $SD = 0.92$), using a Likert scale ranging from 1 (“strongly disagree”) to 5 (“strongly agree”) with a neutral center. Table 1 shows participants’ primary means of transportation by age group. Younger participants were college undergraduates recruited from psychology courses at Florida State University and compensated with course credit, while older adult participants were recruited from the Tallahassee metropolitan area and compensated \$5 for their participation. Younger participants learned about the study through an online experiment sign-up system hosted by the university, and could be completing the experiment as either a course requirement or as extra credit, but this information was not available to the experimenters. Potential community-dwelling older adult participants were contacted using a variety of techniques, including print advertisements, mailings, and in-person community outreach.

2.2 Materials

The primary dependent variable, valuation of an Active Blind Spot Detection System, was measured using one of two (small or large amount, counter-balanced within age groups across participants), four to five step staircase procedures (see Figure 1 for large amount condition example) where individuals were asked to express a preference between two options for each item: an Active Blind Spot Detection (ABSD) system that will be installed at no cost on their current vehicle, or a monetary prize (\$25-\$950). The monetary value of the initial option was set at \$250 for the small condition and \$500 for the large condition, with subsequent values ranging between \$25-\$475 and \$50-\$950, respectively. Dual conditions were utilized to account for an anchoring effect (Kahneman & Tversky, 1974) based on the initial-decision monetary option amount.

Over the course of the measure, a choice of the ABSD system in the previous item increased the monetary offer in the subsequent item, while a choice of the monetary prize lowered the value of the monetary offer. Over the course of four to five decision scenarios, participants reached a final scenario with monetary rewards ranging from \$25-\$475 in \$50 increments in the small scenario, and from \$50-\$950 in \$100 increments in the large scenario. Perceived value of the ABSD system was calculated as the midpoint between items in which a crossover in choice was observed. As illustrated in Figure 1, if participants indicated a preference for the ABSD system over the \$700 reward in step 2 but prefer the monetary reward of \$750 over the system in step 4, perceived value of the ABSD system is calculated

as \$725. This final perceived value is described by one of twenty amounts, ranging from \$12.50-\$487.50 in \$25 increments in the small scenario and \$25-\$975 in \$50 increments in the large scenario.

Along with the experimental items, participants also provided basic demographic information (age, gender, race, income, education, technology self-efficacy, and driving habits) along with additional items used to gauge the individual's familiarity and willingness to use related to various advanced driving assistance systems (ADAS), including: lane-departure warning systems, automatic lane centering, emergency braking systems, adaptive cruise control, and self-parking systems. These ADAS items were both measured on a five item likert scale ranging from "very familiar/likely to use" to "I don't know what it is/very unlikely to use". Participants also completed a 36-item self-reported vision measure adapted from a previously constructed questionnaire, "Your Vision: A Survey by the Vision Laboratories of Northwestern University and The University of Calgary" (Sekuler, Kline, & Kosnik, 1988), measuring self-perceived visual performance in both general (18 items) and driving-related scenarios (18-items).

2.3 Procedure

Participants first answered five basic demographic items, after which they were asked to read a paragraph describing an ABSD system:

Blind spot detection systems have existed for over a decade and use ultrasonic or radar sensors to monitor the driver's blind spot for cars coming up behind or alongside them when changing lanes at high or low speeds. If the driver's turn signal is on and the lane the driver is merging in to is occupied (or soon to be occupied) by a passing motorist, the system alerts the driver to refrain from changing lanes by using a flashing light on the relevant side-view mirror, followed by a steering wheel vibration if the light is not heeded. This lane-change collision warning persists until the passing car in the adjacent lane is ahead of the driver.

After reading the paragraph, participants were shown a 44 second video demonstrating how an ABSD system operates. The video was produced and provided by BMW, used with permission and with the branding watermark removed from the video. The brand was not otherwise mentioned by the actor or visible in other areas of the video (the original watermarked video is available online for reference; BMW USA, 2012). They then completed either the small anchored or large anchored experimental items measuring perceived value of the hypothetical ABSD system. Participants then completed the ADAS opinions and self-reported vision measures.

Data was collected using Qualtrics and processed using SPSS 22. An exploratory factor analysis was carried out on the vision and driving questionnaire data using principal components analysis for the purposes of dimension reduction. T-tests were used to assess differences between younger and older participants' valuations of the ABSD system. Three regression models were calculated for the ABSD valuation data: one with only age as a predictor; another that accounted for age, gender, income, and technology self-efficacy; and the final model that included the previously mentioned predictors as well as the calculated

vision-driving factor scores, which were used over the vision factor scores due to their relevance to the driving situation in an effort to keep the number of predictors manageable.

Three regression models were also calculated for willingness to use other types of ADAS. The first model treated age as a continuous variable; the second model included age, gender, income, technology self-efficacy, and prior familiarity of the ADAS in question; and the third model added the vision-driving factor scores to the demographic factors and prior familiarity rating included in the first two models.

3. RESULTS

3.1 Self-Reported Vision Survey

Following the analysis procedure previously described in the literature (Kline et al., 1992; McGregor & Chaparro, 2005), data from the 18 vision and 18 vision-driving items from the self-report survey was reduced using a separate exploratory factor analysis for each construct using principal components analysis and varimax rotation. It should be noted that the resulting factor scores are exploratory and should be interpreted with caution, as the sample size in the current study ($N = 89$) is low.

Similar to the factor analysis reported by McGregor & Chaparro (2005), vision-related items were found to load on five factors. After investigation of the factor loading of the individual items, these factors were given the following titles: “Factor 1: Visual Search and Light Adjustment” (36.39% of variance) described by items related to locating and reading a sign amongst many other signs and adjusting to changes in lighting quality, “Factor 2: Age-related Visual Difficulties” (8.39% of variance), described by items related to taking longer for visual tasks and dealing having difficulties with miscellaneous age-related visual difficulties (e.g., trouble reading cluttered, moving, or poorly lit text, trouble with contrast sensitivity and light adjustment) “Factor 3: Reduced Static Acuity” (7.25% of variance) described by items related to reading small print or material close up, “Factor 4: Glare and Challenging Reading Conditions” (6.47% of variance) described by items related to dealing with glare and reading moving material or in reading in poor lighting, and “Factor 5: Bumping into Objects in Periphery” (5.65% of variance) described by items related to bumping into things that were just outside your field of vision or that you should have seen. See Table 2 for the means, standard deviations, and factor loadings of the general vision items.

Driving-related items were found to load on six factors, also matching the loading found by McGregor & Chaparro. For our analysis, these factors were given the following titles: “Factor 1: Night/Dusk Driving & Perception Reaction Time” (26.24% of variance) described by items related to night/dusk driving and not being able to process stimuli fast enough to react properly, “Factor 2: Instrument Panel Difficulties & Desire for Illumination” (8.8% of variance) described by items related to difficulties reading the instrument panel or insufficient illumination from streetlights or taillights, “Factor 3: Cabin Visual Obstructions” (8.57% of variance) described by items related to visual obstructions from inside the cabin (steering wheel, dashboard, unclean windshield), “Factor 4: Headlight Glare” (7.7% of variance) described by items related to issues with glare from headlights, “Factor 5: Issues

with Longitudinal & Latitudinal Driving Maintenance” (6.95% of variance) described by items related to difficulty judging driving speed and maintaining lane position, and “Factor 6: Unnoticed Vehicles & Poor Lighting” (6.36% of variance) described by items related to unnoticed vehicles when merging or in poor light conditions. See Table 3 for the means, standard deviations, and factor loadings of the vision-driving items.

3.2 Valuation of ABSD System

Perceived value in dollars for the ABSD System was calculated for all individuals as described in the methods section. A significant difference was found for both the small amount ($M_{Younger} = \$228.75$, $SD = \$188.53$; $M_{Older} = \$392.31$, $SD = \$178.89$; $t(44) = 3.00$, $p = .004$) and large amount ($M_{Younger} = \$382.50$, $SD = \$334.93$; $M_{Older} = \$761.96$, $SD = \$343.85$; $t(41) = 3.65$, $p = .001$) conditions, with older participants valuing the ABSD significantly more than younger participants in both conditions.

The relationship between age and perceived value of the ABSD system was further investigated by fitting regression models to the data, treating age as a continuous variable (age was also analyzed as a dichotomous variable, but this did not change the observed results). Three models were fit to the data (Table 4), the first including only age as a predictor, then controlling for demographic factors (gender, income, and technology self-efficacy) in the second model, and adding the vision-driving factor scores to an exploratory third model. In the first model, increased age ($\beta = .51$, $t = 3.78$, $p < .001$) was found to significantly predict an increase in the perceived value of the ABSD system in the large condition ($R^2 = .26$, $F(1, 41) = 14.30$, $p < .001$). This relationship between increased age ($\beta = .60$, $t = 2.31$, $p = .026$) and increasing perceived value of the ABSD system persisted when controlling for demographic variables in the second model ($R^2 = .31$, $F(4, 38) = 4.17$, $p = .007$). This relationship became non-significant with the addition of the vision-driving factor scores in the exploratory third model ($F(10, 32) = 1.78$, $p = .11$).

In the small condition, age ($\beta = .40$, $t = 2.90$, $p = .006$) was found to be significant as the sole predictor in the first model ($R^2 = .16$, $F(1, 44) = 8.42$, $p = .006$), indicating an increase in the perceived valuation of the ABSD system with increasing age. When controlling for other demographic factors in the second model ($R^2 = .26$, $F(4, 41) = 3.53$, $p = .014$), age was not found to be a significant predictor ($\beta = .25$, $t = 1.54$, $p = .132$). The third exploratory model was not found to fit the dataset ($R^2 = .30$, $F(10, 35) = 1.47$, $p = .19$).

3.3 Willingness to Use Other ADAS

Table 5 shows the results of each regression model computed for each ADAS investigated. Significant results are reported by system in sections 3.3.1- 3.3.3.

3.3.1 Lane-Departure Warning Systems—The first model with age as the sole predictor was found to be significant ($R^2 = .18$, $F(1, 87) = 19.02$, $p < .001$), with increasing age ($\beta = .42$, $t = 4.36$, $p = .001$) significantly predicting greater willingness to use lane-departure warning systems. The second model was also found to be significant ($R^2 = .32$, $F(5, 83) = 7.86$, $p < .001$), with age ($\beta = .43$, $t = 3.33$, $p = .001$) and prior familiarity ($\beta = .37$, $t = 3.76$, $p < .001$) significantly predicting more willingness to use a lane-departure warning

system. The third exploratory model that included vision-driving factor scores was also significant ($R^2 = .38$, $F(11, 77) = 4.34$, $p < .001$), with greater willingness to use a lane-departure warning system significantly predicted by increasing age ($\beta = .38$, $t = 2.68$, $p = .009$) and higher levels of prior familiarity ($\beta = .32$, $t = 3.16$, $p = .002$).

3.3.2 Automatic Lane Centering—The first model with age as the sole predictor was found to be significant ($R^2 = .07$, $F(1, 87) = 6.74$, $p = .011$), with increasing age ($\beta = .27$, $t = 2.60$, $p = .011$) significantly predicting greater willingness to use an automatic lane centering system. The second model was significant ($R^2 = .13$, $F(5, 83) = 2.55$, $p = .034$), with greater willingness to use an automatic lane centering system significantly predicted by increasing age ($\beta = .33$, $t = 2.24$, $p = .028$). The exploratory third model was not found to be significant in the case of automatic lane centering systems ($F(11, 77) = 1.82$, $p = .065$).

3.3.3 Adaptive Cruise Control—The first model with age as the sole predictor was not found to be significant ($R^2 = .03$, $F(1, 87) = 2.87$, $p = .094$). The second model was found to be significant ($R^2 = .19$, $F(5, 83) = 3.76$, $p = .004$), with increasing age ($\beta = .34$, $t = 2.43$, $p = .017$) and greater prior familiarity ($\beta = .32$, $t = 2.93$, $p = .004$) significantly predicting greater willingness to use adaptive cruise control. The exploratory third model was also found to be significant ($R^2 = .28$, $F(11, 77) = 2.71$, $p = .005$), with greater willingness to use adaptive cruise control significantly predicted by increasing age ($\beta = .32$, $t = 2.10$, $p = .039$), higher levels of prior familiarity ($\beta = .27$, $t = 2.43$, $p = .018$), and higher levels of the first vision-driving factor “night/dusk driving & perception reaction time” ($\beta = .23$, $t = 2.10$, $p = .039$).

4. DISCUSSION

4.1 Valuation of ABSD System

Older adults were found to value the ABSD system more than younger adults in both the small and large anchor conditions, with older adults nearly doubling younger adults’ valuation of the ABSD system in the large anchor condition ($M_{\text{Younger}} = \$382.50$ vs. $M_{\text{Older}} = \$761.96$). Increased age was predictive of higher valuation of the ABSD system controlling for gender, income, and technology self-efficacy in the large anchor condition. Interestingly, self-reported issues with vision in driving scenarios were not found to significantly predict participants’ valuation of the ABSD system.

The valuations of the ABSD system in this study were much closer to the actual value of an aftermarket blind spot monitor (suggested retail price of \$250, with estimate of 4 hours of labor for professional installation; Travers, 2013) than what Schulz and colleagues’ (2014) participants were willing to pay for the kitchen and personal care QoLTs versus their actual cost. It is important to note beforehand that the method of obtaining valuations in the current study was quite different than that used by Schulz et al. (2014), but this difference in valuations could be due to a number of other factors. One might be the personal nature of the assistance that the QoLTs provide. Being able to prepare their own food and/or maintain their own hygiene past a certain age might be activities that are a point of pride for the older individual, or activities they have trouble envisioning having difficulties with to the point that they feel it is necessary to pay for assistive technologies. Another reason might be the

fact that unsafe driving is not only dangerous to the driver, but to other motorists as well, whereas difficulties preparing food and/or cleaning oneself only affect the individual that has such difficulties. It is possible they discount their own health and safety relative to their ability to safely carry out those activities, but once their actions have the potential to harm others, as is the case in driving, a sense of social responsibility might make them more willing to pay for technological assistance. Social influence is an important component in theories of technology adoption (e.g., UTAUT) and needs further exploration in driving technology. Younger and older age cohorts may weight social responsibility differently.

4.2 Willingness to Use Other ADAS

Increased age and greater familiarity were both found to significantly predict greater willingness to use lane-departure warning systems and adaptive cruise control, but of these two variables, only prior familiarity predicted willingness to use emergency braking systems. This suggests the mere-exposure effect (Zajonc, 1968) might be at play when it comes to willingness to use ADAS systems. Adaptive cruise control was one of the first advanced in-vehicle technologies introduced (de Winter, Happee, Martens, & Stanton, 2014), affording more time to establish familiarity with its functionality than more recently developed ADAS, and this finding of prior familiarity's importance in predicting willingness to use ADAS bodes well for the future adoption attitudes and rates of more recently developed ADAS.

Willingness to use adaptive cruise control and emergency braking systems were both significantly predicted by higher levels of the first vision-driving factor “night/dusk driving & perception reaction time” that dealt with difficulty seeing distant objects at night, difficulties with glare on the windshield at sunset or from oncoming headlights, being surprised by the sudden appearance of vehicles or objects at dusk, or failing to make a turn because you couldn't read the street sign soon enough. Both of these systems aid in detecting and reacting to obstacles (moving at relative speed to the vehicle, in the case of adaptive cruise control) in the vehicle's path, and could provide assistance in lower light and high glare conditions, enhancing obstacle detection and/or providing timely intervention when a crash is imminent. Interestingly, Eby et al. (2015) suggest that adaptive cruise control can help achieve better safety outcomes for older drivers if paired with some type of forward collision warning.

4.3 Limitations

One limitation of the current study was its reliance on self-report data, and lack of objective measurements of vision and other factors that might affect participants' abilities to check their blind spot while driving such as neck/trunk range of motion, useful field of view, as well as cognitive abilities such as spatial cognition. One could reasonably argue that self-reports of visual difficulties are sufficient for the current study, as early awareness of deficiencies in spatial vision function and depth perception have been linked to older drivers curtailing their driving, though decrements in visual attention may go unnoticed by the older driver and hence no precautionary measures might be taken (West et al., 2003). An experimental visual attention task or the measurement of neck/trunk range of motion, might add objective support to the subjective survey data, and might have been helpful in

explaining a greater portion of the variance in the valuation of the ABSD system. Additionally, using a survey measure more focused on spatial cognition or peripheral vision while driving might have been helpful, as the questionnaire used in the current study had a large number of lighting and glare items that were not particularly relevant to the experimental question. A more expansive set of demographic variables covering driving experience (e.g., number of years driving, lifetime mileage estimates, crash history) and vehicle ownership history (e.g., history of vehicle purchasing, purchasing and installation of after-market vehicle devices) would also be useful additions for future studies investigating the topic of valuation of ABSD systems and other ADAS.

As stated previously, due to the low sample size the vision-related factor scores from the current study should be viewed as exploratory, though it has been shown that exploratory factor analysis can yield reliable results for sample sizes as low as 10 for well-conditioned data (i.e., high loadings, low number of factors, and high number of variables; de Winter, Dodou, & Wieringa, 2009). The moderate to high communalities found in both factor analyses (vision factor analysis communalities averaged .641, ranged .402-.781; vision-driving factor analysis communalities averaged .577, ranged from .471-.767), the number of factors (5 for vision items, 6 for vision-driving items), and the ratio of variables per factor (18:5 for vision items, 18:6 for vision-driving items) suggest that while the data are not “well-conditioned” enough for reliable results with a sample size of 10, the sample size of 89 in the current study should be useful for exploratory purposes. Further, the factor structure resembles that obtained by McGregor and Chaparro (2005).

Another limitation of the current study concerns the older sample's representativeness in terms of income, health, and education. Though income was not a significant predictor of the valuation of the ABSD system, the older participants in this study might be more willing to place a higher monetary value on the system than the lower income younger participants or older adults with less expendable income. The older adults were healthy enough to drive themselves to the lab (in most cases) and complete the experiment as well, so these results might be closer to a best-case-scenario than representative of all older adults. Another sampling limitation with regards to the younger sample is marked by a common shortcoming in aging research: namely the mismatch in recruitment procedure for older and younger adults based on differences in participant availability between populations. As with most research that relies on undergraduate samples of convenience, one must interpret the findings knowing that the younger sample is a little WEIRD (Western, educated, industrialized, rich, and democratic; Henrich, Heine, & Norenzayan, 2010).

5. CONCLUSIONS

This study extends the literature on valuation of assistive devices aimed at supporting safety and independence to the advanced in-vehicle technologies. Age was found to be predictive of higher valuation of ABSD systems in both of the anchor conditions, and older adults in the large condition valued the system almost twice as much as younger adults. Older participants' valuation of the ABSD system also showed greater calibration to the system's actual cost relative to the kitchen and personal care QoLTs previously studied by Schulz et al. (2014), suggesting that older adults might be more willing to pay for this technology

without the need of a subsidy. Interestingly, younger adults' valuations of the ABSD system were within the actual price range of aftermarket blind spot detection systems, despite younger adults in the current sample being less likely to drive their own vehicle as their primary means of transportation than older adults. Income was not found to be a significant predictor of system valuation in either the small or large anchoring conditions, and it was not a significant predictor of willingness to use other ADAS as well.

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Highlights

- Older drivers valued ABSD about twice as much as younger drivers.
- Income was not found to predict ABSD system valuation or willingness to use other ADAS.
- Willingness to use other ADAS was predicted by age, familiarity, and visual factors.

Figure 1.

Illustration of staircase procedure for “large” condition.

Note: * indicates that step is not always presented and dependent on previous choices.

Table 1

Primary Means of Transportation

	Younger	Older
Drive their own vehicle	22	48
Ride from family/friends	3	0
Public transportation	3	1
Bike	2	0
Walk	8	0
Other	2	0

Younger adults were less likely to drive their own vehicle as their primary means of transportation than older participants ($p < .001$; Fisher's exact test)

Table 2

Means, Standard Deviations, and Factor Loadings for General Vision items.

	Younger		Older		Factor				
	M	SD	M	SD	1	2	3	4	5
How much trouble do you have adjusting to bright lights when coming out of a dark place, such as going when going into the daylight from a movie theatre?	1.60	0.63	1.96	0.73	0.67	-0.25	0.38	0.20	0.13
Do you have trouble reading the credits on TV because they move too fast?	1.90	0.81	2.82	0.75	0.21	0.16	0.29	0.61	-0.16
Do you have trouble recognizing things or people at night because of your vision?	1.88	0.82	2.22	0.87	0.61	-0.03	0.30	0.26	-0.04
How much more slowly do you generally read now than in the past?	1.30	0.56	1.78	0.59	0.00	0.74	0.15	0.22	0.00
Do you have trouble seeing something when lights off to the side are shining into your eyes? For example, do you have trouble seeing someone's face when a light off to the side is shining into your eyes?	2.05	0.90	2.59	0.73	0.37	0.06	0.28	0.59	0.03
How much trouble do you have seeing something when lights are being reflected from it? For example, do you have trouble watching TV when the room lights are shining on the screen?	1.95	0.81	1.94	0.69	0.05	0.20	-0.20	0.64	0.22
Do you have visual problems like blurry vision or eye strain when reading or doing close work?	1.68	0.86	1.98	0.90	0.19	0.08	0.56	0.06	0.20
Do you have trouble visually locating a familiar sign because it is among many other signs? For example, do you have trouble locating a restaurant sign on a street filled with other signs?	1.45	0.60	2.27	0.78	0.80	0.32	0.01	0.13	0.05
Do you have problems actually reading a particular sign when it is midst of other signs? For example, do you have problems reading a sign on a city street because it is embedded in a clutter of other signs?	1.68	0.66	2.41	0.79	0.76	0.45	0.01	0.05	-0.01
Do you bump people or other things because they were just outside of your field of vision and you did not see them?	1.47	0.60	1.35	0.52	0.06	0.03	-0.05	0.11	0.84
How much trouble do you have reading the small print, such as numbers in the phone book or classified ads?	1.28	0.51	2.24	0.85	0.09	0.26	0.79	0.19	-0.06
Do you have trouble reading a sign or recognizing a picture because it is moving, such as an ad on a passing bus or truck?	1.55	0.71	2.18	0.73	0.56	0.41	0.22	0.24	0.11
Do you have trouble adjusting from bright to dim lighting, such as when going from daylight into a dark restaurant or movie theater?	1.58	0.81	2.37	0.81	0.54	0.15	0.56	0.04	0.12
Do you have trouble seeing indoors when the lights are dim, for example, reading a menu in a dimly lit restaurant?	1.40	0.59	2.45	0.77	0.18	0.48	0.41	0.52	0.07
Do you accidentally bump into doorways, walls, or other things that you should have seen but did not, even though you were not in a hurry?	1.50	0.68	1.55	0.74	0.04	0.18	0.29	-0.04	0.80
Do you have trouble distinguishing between dark colors, such as when sorting dark blue and black socks?	1.50	0.82	2.10	0.92	0.28	0.58	0.01	0.19	0.18
Do you take more time now than in the past doing things that depend on your vision, such as going down steps, sewing, playing cards, or other hobbies, etc.?	1.30	0.52	2.39	1.02	0.25	0.60	0.46	-0.07	0.13
Do you have difficulty seeing clearly outdoors at dusk just after sunset? For example, do you have difficulty reading unlit billboards and signs, or recognizing other people's faces at dusk?	1.38	0.63	2.18	0.78	0.55	0.55	0.29	0.22	0.13

Note: All items were presented on a 4-point Likert scale where 1 = Never/None at all, 2 = Rarely/A little, 3 = Occasionally/Quite a bit, 4 = Frequently/A lot. Factor loadings |0.40| are shown in bold.

Table 3

Means, Standard Deviations, and Factor Loadings for Driving-Related Vision Items.

	Younger		Older		Factor					
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	1	2	3	4	5	6
During night driving do you have problems seeing because of oncoming headlights, even when they are properly dimmed?	1.80	0.76	2.45	0.68	0.55	0.24	0.02	0.55	-0.16	0.20
During night driving, how much do headlights reflected in your rearview mirror bother you?	1.97	0.66	2.24	0.78	0.02	0.13	0.06	0.70	0.04	-0.03
When driving in the city at night have you wished the street/highway lights would be turned on earlier in the evening?	1.63	0.70	1.76	0.83	0.18	0.58	0.36	-0.06	-0.20	0.46
How much difficulty do you have keeping your instrument panel in focus at night because it is just too dim?	1.15	0.36	1.12	0.39	-0.23	0.73	0.23	0.29	0.16	0.05
Do you have difficulty seeing the taillights of other vehicles because they are not bright enough?	1.35	0.62	1.49	0.58	0.44	0.64	-0.06	-0.02	0.17	0.03
When lighting conditions are poor (such as at dusk), are you ever surprised by the sudden appearance of other vehicles or objects that were there, but you did not see them until the last moment?	1.53	0.60	1.88	0.53	0.52	0.38	-0.19	-0.11	0.08	0.43
During night driving do distant objects such as signs or license plates seem blurry or out-of-focus?	1.88	0.82	2.45	0.79	0.73	0.16	0.07	0.14	-0.05	0.02
During night driving does your instrument panel seem blurry or out-of-focus, even though it is bright enough?	1.25	0.49	1.31	0.65	0.26	0.71	0.07	0.13	0.08	-0.23
How much difficulty do you have ignoring or looking past dirt, haze, or rain drops on your windshield to see clearly objects that are beyond your car?	1.60	0.63	1.69	0.58	0.22	-0.06	0.77	0.04	0.08	0.02
Do you ever fail to make a turn onto a street you want because you did not read the name on the street sign in time?	2.40	0.93	2.45	0.65	0.50	0.04	0.16	0.00	0.19	0.45
Do you ever have difficulty staying in your driving lane?	1.45	0.68	1.35	0.52	0.33	0.21	0.23	-0.35	0.60	-0.21
Do other vehicles seem to come into your peripheral vision unexpectedly when you are looking straight ahead?	1.72	0.64	1.82	0.67	0.14	0.38	-0.22	0.12	0.46	0.30
Do you have difficulty judging your speed without looking at the speedometer?	2.03	0.80	2.04	0.58	-0.03	0.07	0.13	0.25	0.79	0.24
When merging into traffic are you ever "surprising" by a vehicle that you did not notice until it was quite close to you?	2.03	0.70	2.20	0.54	0.07	-0.10	0.14	0.07	0.14	0.82
Do most other vehicles seem to be going too quickly for you when you are driving?	1.70	0.82	2.24	0.88	0.43	0.15	0.44	0.19	0.13	0.15
Does the steering wheel or dashboard ever obstruct your vision when you are driving?	1.23	0.48	1.12	0.39	-0.10	0.19	0.78	0.04	0.04	0.11
Do you have difficulties seeing due to the glare from your windshield when the sun is low in the sky?	2.05	0.85	2.69	0.68	0.59	-0.02	0.17	0.24	0.35	0.06
Do you have problems seeing due to the headlight glare from oncoming vehicles at night?	2.17	0.81	2.55	0.61	0.39	0.00	0.08	0.71	0.28	0.03

Note: All items were presented on a 4-point Likert scale where 1 = Never/None at all, 2 = Rarely/A little, 3 = Occasionally/Quite a bit, 4 = Frequently/A lot. Factor loadings |0.40| are shown in bold

Table 4

Regression models: Predicting valuation of ABSD systems in both Small and Large Conditions

	Small Amount (\$250 anchor)				Large Amount (\$500 anchor)			
	β	R^2	R^2	F	B	R^2	R^2	F
Model 1		0.16		8.42**		0.26		14.30***
Age	0.40**				0.51***			
Model 2		0.26	0.1	3.53*		0.31	0.05	4.17**
Age	0.25				0.60*			
Gender	-0.25				0.1			
Income	0.04				0.06			
Technology Efficacy	-0.28				0.23			
Model 3		0.3	0.04	1.47		0.36	0.05	1.78
Age	0.24				0.46			
Gender	-0.25				0.06			
Income	0.01				0.08			
Technology Efficacy	-0.26				0.16			
Vision: Driving Factors Night/Dusk Driving & Perception Reaction Time	0.13				0.13			
Instrument Panel Difficulties/Desire for Illumination	-0.05				0.19			
Cabin Visual Obstructions	0.05				0.01			
Headlight Glare Issues	0.06				0.06			
Longitudinal/Latitudinal Driving Maintenance Issues	-0.12				-0.1			
Unnoticed Vehicles & Poor Lighting	-0.12				-0.04			

Note:

*
<.05**
<.01***
<.001

Table 5

Regression Models: Willingness to Use Other ADAS

	Lane Departure Warning				Automatic Lane Maintain				Adaptive Cruise Control				Emergency Braking System				Self-Parking System			
	β	R^2	R^2	F	β	R^2	R^2	F	β	R^2	R^2	F	β	R^2	R^2	F	β	R^2	R^2	F
Model 1		0.18		19.02***		0.07		6.74*		0.03		2.87		0.01		0.496		0.004		0.31
Age	0.42***				0.27*				0.18				0.08				0.06			
Model 2		0.32	0.14	7.86***		0.13	0.06	2.55*		0.19	0.16	3.76**		0.12	0.11	2.22		0.055	0.05	0.97
Age	0.43***				0.33*				0.34*				0.27				0.1			
Gender	0.09				0.13				0.15				0.12				0.16			
Income	0.12				0.03				0.04				-0.08				0.037			
Technology Efficacy	0.01				0.12				0.2				0.08				-0.08			
Prior Familiarity	0.37***				0.2				0.32***				0.3*				0.19			
Model 3		0.38	0.06	4.34***		0.21	0.08	1.82		0.28	0.09	2.71**		0.24	0.12	2.21*		0.11	0.06	0.85
Age	0.38**				0.29				0.32*				0.18				0.08			
Gender	0.1				0.13				0.19				0.15				0.1			
Income	0.11				-0.03				-0.01				-0.16				-0.004			
Technology Efficacy	0.03				0.15				0.23				0.12				-0.06			
Prior Familiarity	0.32**				0.17				0.27*				0.26*				0.17			
Vision: Driving Factors Night/Dusk Driving & Perception Reaction Time	0.13				0.22				0.23*				0.34**				0.04			
Instrument Panel Difficulties/Desire for Illumination	-0.04				-0.004				-0.1				0.1				-0.01			
Cabin Visual Obstructions	0.02				0.02				0.01				-0.08				0.12			
Headlight Glare Issues	0.02				-0.06				-0.14				-0.01				0.03			
Longitudinal/Latitudinal Driving Maintenance Issues	-0.18				-0.18				-0.12				-0.12				-0.2			
Unnoticed Vehicles & Poor Lighting	-0.13				-0.03				-0.08				-0.05				0.04			

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Note:

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