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OLDER ADULT DRIVERS' CHALLENGES AND IN-VEHICLE TECHNOLOGY ACCEPTANCE

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Abstract: Driving is an essential activity in living a fulfilling lifestyle. Older adults, like the rest of the population, require a means of transportation to participate in important lifestyle choices; however, declines in their sensory, motor, perceptual, and cognitive abilities limit their driving capabilities. These limitations motivated this study to investigate older adult drivers' driving challenges by conducting a questionnaire. The in-vehicle technologies which mitigate these challenges were identified. In this study, the acceptance of the identified technologies is explored by conducting a second questionnaire. A four dimensional model which included perceived usefulness, perceived ease of use, perceived safety, and perceived anxiety is considered in the second questionnaire. In total, 250 older adult drivers participated in these questionnaires. The responses obtained from both questionnaires identified potential challenges that they were facing and whether they intend to use the identified in-vehicle technologies. Having more information about the acceptance of these technologies can help engineers better understand the factors that make technologies useful to older adult drivers, and thus improve their driving safety.

Keywords: older adult drivers, driving safety, challenging driving situation, in-vehicle technology, driving assistance technology, older adult drivers' technology acceptance.

1. Introduction

In developed countries, the population of older adult drivers is predicted to be the fastest growing driver segment in the next ten years (Casutt *et al.,* 2014). As quality of life in these countries increases, older adult drivers are more likely to continue driving regardless of their age (Bélanger *et al.,* 2010). Their tendency to continue driving is increasing while complicating factors such as age-related sensory, physical, and cognitive changes, as well as complex modern traffic environments, pose increasing risks to the older adult populations. In addition to these risks, if older adult drivers involved in crashes, they are more fragile and more likely to incur fatal injury while today's health care costs are unendurable to them (Schulz *et al.,* 2015). The trends are working unfavorably in both directions, while older adult driver population and their tendency to continue driving are increasing, their driving capabilities are decreasing due to the normal aging process (Musselwhite *et al.,* 2015). This negative correlation and other mentioned risks have created increasing safety issues for older adult drivers. A variety of in-vehicle technologies has been developed and implemented in modern vehicles to mitigate driving challenges. In order to develop and employ technologies

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which address the needs of older adults, it is important to understand older adult driver acceptance on these technologies. The important questions are:

- What driving situations pose challenges to older adult drivers?
- What kind of assistance do they need in those situations?
- Which in-vehicle technologies can provide the needed assistance?
- What are the highlighting dimensions of older adult drivers' in-vehicle technology acceptance?

To answer these questions, a survey was conducted to identify those challenging driving situations that older adult drivers tend to avoid or feel reluctant to engage. Older adult drivers were also surveyed on their demographic, driving experiences, health concerns, crash experiences. After identifying the driving challenges and type of required assistance, this study explored feasible in-vehicle technologies that could provide assistance to older adult drivers. The study focuses on currently available, lower-level in-vehicle technology that could enhance older adult drivers' driving and their driving safety. Through the questionnaires, we explored older adult drivers' acceptance of identified in-vehicle technologies such as Automatic Windshield Wipers (AWW) system, Night Vision Camera (NVC), Adaptive Cruise Control (ACC), Lane Departure Warning (LDW) system, and Side View Assist (SVA) system, Automated Pedestrian Detecting system (APD).

2. Background

2.1. Older Adults and Driving Risks

The population of older adult drivers is increasing in the United States. With the aging of the Baby Boom generation, census data estimates that the population over 65 years old will double by 2050 (Ortman *et al.,* 2014). To live a fulfilling independent lifestyle, older adults need to have access to goods and services as well as to social and leisure activities. Driving is the easiest, but also the riskiest, way to access these activities (Hojjati-Emami *et al.,* 2014). The American Association of Retired Persons reported drivers over 65 make 90% of their trips in private vehicles as a primary means of transportation (Houser, 2005). Although age cannot be a reliable indicator of an individual's driving performance (Siren and Meng, 2012), older adult drivers are noted for their decline in sensory and motor capabilities, and increase in perceptual and cognitive impairment (Horswill *et al.,* 2008; Motamedi and Wang, 2016; Pavlou *et al.,* 2016). (Dawson *et al.,* 2009) mentioned that by 2030 older adult drivers will account for one fourth of driver fatalities. These findings cause concerns about the potential driving risks, which older adult drivers pose to themselves and to other road users. While driving is an essential activity in the older adult lifestyle (Rosenbloom *et al.,* 2012), an important question needs to be addressed: "How can driving risks associated with older adult drivers be reduced?"

In order to answer this question, challenging driving situations identified by older adult drivers were in need of investigation. A review study of older adult drivers and their crash involvement, which included articles published in North America since 1990, found that these drivers are more likely to have been at fault in intersection crashes than younger drivers. They also experienced a high rate of crashes when they were turning, particularly when making left turns (Cicchino and McCartt, 2015; Mayhew *et al.,* 2006).

However, subjective studies have shown that older adult drivers report decreased driving abilities in certain conditions, including complex intersections, highways, difficult weather conditions, and driving at night (Levin *et al.,* 2012). Moreover, previous subjective research has identified that older adult drivers avoid driving in challenging situations, such as at night, in bad weather, on slippery roads, and in heavy traffic (Charlton *et al.,* 2006). According to a survey conducted in 2012, with participation of 1,962 older adult drivers, night driving, bad weather, unfamiliar areas, heavy traffic, and long distances were found to be more challenging for older adult drivers compared to drivers in their 40s (Henriksson *et al.,* 2014). These challenges possibility were caused by health concerns such as vision, cognitive and some functional limitation of older adults (MacLeod *et al.,* 2014). Key questions remained unanswered in mentioned studies are how could older adults' driving safety be enhanced and what driving assistance technology could be provided? This study identified possible difficulties and challenges facing older adult drivers and explored some modern in-vehicle technologies to address these questions.

2.2. In-vehicle Technologies

In-vehicle technologies have been categorized according to a scale ranging from 0 to 5 (Mehler et al., 2014) associated with their level of automation. At Level-0 are technologies with a degree of functionality that may provide information assistance but no automated control of the vehicle. In-vehicle technologies in the higher levels have more automated control of the vehicle. Although a Level-4 systems such as self-driving cars seem to be a final solution for challenges facing older adult drivers, we are not quite ready for it yet (Reimer, 2014). Therefore, in this study, we focused on lower level automation systems which could improve driver safety in identified driving situations based an initial questionnaire. An apparent and important reason to choose low-level systems is the limited cognitive capacity of older adult drivers, as mentioned before (Siren and Meng, 2012). The recent research revealed that age had a negative effect on the effectiveness of high level in-vehicle systems on safety (Son *et al.,* 2015). The systems may distract older adult drivers instead of increasing their safety while driving (Lam, 2002). Thus, It is imperative to investigate older adult drivers' acceptance regarding the available lower-level technologies and the effective adoption of these technologies which have an essential role in transitioning older adult drivers toward fully automated vehicles (Reimer, 2014).

2.3. Technology Acceptance

Many new driving assistance technologies are developed to help resolve some specific driving challenges. However, these new technologies could not benefit the users, especially the older adult users unless they are accepted. One of the early frameworks which explained technologies acceptance is the Technology Acceptance Model (TAM) (Davis, 1989). This model found perceived usefulness and perceived ease of use as main effective factors on users' decision. This model was extended to TAM2 (Venkatesh, and Davis, 2000), TAM3 (Venkatesh and Bala, 2008) and the Unified Theories of Technology Acceptance Model (UTAUT) (Venkatesh *et al.,* 2003) which integrated different models on the base of TAM.

TAM and its extended models were used and applied in different contexts while the original context of this model was desktop computer (Osswald *et al.,* 2012). For a driving environment, there has been limited research considering factors such as motion and environmental conditions. (Osswald *et al.,* 2012) introduced Car Technology Acceptance (CTAM) for fuel consumption and traffic emissions in-vehicle technology application. This model basically added perceived anxiety and perceived safety as relevant and additional dimensions for the UTAUT model (Levin *et al.,* 2012). (Madigan *et al.,* 2016) stated that the reliability of the CTAM's scales were well demonstrated but the impact of these factors on behavioral intentions of driving information technology systems was not investigated. Moreover, all the above mentioned models might be age, gender, and experience sensitive. Therefore, in this study we employed the TAM model with the new introduced dimensions of CTAM such as perceived anxiety and perceived safety to assess the acceptance of in-vehicle technologies in a driving environment.

3. Methods

To gain insights into the mobility challenges facing older adults and their acceptance of in-vehicle technologies, two questionnaires were developed and administered to a number of older adult drivers in Rhode Island. 16.1% of the population in this state are 65 and older which ranks Rhode Island the 9th oldest state in the nation (Census, 2015). The study conducted in Rhode Island could be easily modified to suit the needs of other states to assess their aging drivers.

The first questionnaire was designed to study the situations that older adult drivers identified as challenging. A total of 135 subjects participated. After finding challenging driving situations and the assistance that older adult drivers need in these situations, a number of in-vehicle driving assistance technologies were identified and selected. Then in the second questionnaire, older adult drivers were asked about acceptance of these in-vehicle technologies. This questionnaire was developed based on a new adapted conceptual model for older adult drivers' technology acceptance. In this study, the TAM model is adapted for driving environment by adding perceived safety and perceived anxiety dimensions. A total of 115 subjects participated in the second questionnaire. A detailed description of each questionnaire is provided below.

3.1. Questionnaire 1

Questionnaire 1 collected participants' driving profile included demographics, driving experiences, health concerns, and crash experiences. Additionally, each participant was asked to identify the challenge level of 20 specific driving situations on a scale from 1 to 5 with 1 being not challenging and 5 being extremely challenging. These 20 situations are deducted from crash data analysis literature (Mayhew *et al.,* 2006 ; Cicchino and McCartt, 2015; Levin *et al.,* 2012; Charlton *et al.,* 2006; Henriksson *et al.,* 2014) and are summarized in Table 1.

The 135 participants were recruited from the University of Rhode Island, the Osher Lifelong Learning Institute (OLLI), and other local communities such as older adult centers and churches. All participants were living in Rhode Island, holding a valid driver's license, and still driving. It is worth noting that the administration method of this questionnaire was paper-and-pencil. The researchers met all participants in person, explained the purpose of the questionnaire, and gave instructions to the participants. The questionnaire included a total of 28 questions. These questions could be classified into 5 groups -

1. Demographics such as age (including five groups: <60, 60-70, 70-80,80-90, >90) and gender (including two groups: female and male);
2. Driving experiences such as car usage, frequency of driving, and average trip length in time;
3. Health concerns such as memory, vision, hearing, muscle weakness, speaking, balance, pain, heart condition, bones or joints, and breathing;
4. Driving situations where they were at fault in a crash experience in the past 10 years;
5. Challenge rating of each of the 20 specific driving situations in a 1 to 5 Likert scale.

Most of the questions asked the participant to tick boxes with some questions requiring written answers. Lastly, participants were asked if they were interested in taking part in a follow-up questionnaire regarding in-vehicle technology in the future. Through the results of this questionnaire, it was expected that sufficient information could be gathered regarding older drivers driving experiences and their capability of driving in those challenging situations.

Table 1

The Challenging Driving Situation Classifications, the Needed Assistance and Proposed In-vehicle Technologies

Challenging Driving Situation	Grouped Situation	Possible Weakness	Proposed In-vehicle Technology	Provided Assistance	Improvement Made
• Driving in light rain • Driving in light snow • Driving in light fog • Driving in heavy rain. • Driving in heavy snow • Driving in heavy fog.	Weather Condition	Vision Divided attention	Automatic Windshield Wipers (AWW) system	Adapts the speed of wipers according to the precipitation	Reduce drivers' need to multi-tasking Improve speed of processing information and making decisions
• Driving at night on lighted urban roads • Driving at night on unlighted urban roads. • Driving at night on lighted rural roads. • Driving at night on unlighted rural roads	Night Driving	Night vision	Night Vision Camera	Detect objects on road	Improve Low-light vision
• Driving on highways or high-speed roads that familiar with. • Driving on highways or high-speed roads that unfamiliar with.	High Speed Roads	Motion perception Contracts sensitivity Peripheral vision	Adaptive Cruise Control (ACC) Lane Departure Warning (LDW) system	Control the vehicle speed according to other vehicles on the road Keep the vehicle in the lane	Draw attention to approaching traffic Assist the driver in directing his/her attention to Relevant information

Challenging Driving Situation	Grouped Situation	Possible Weakness	Proposed In-vehicle Technology	Provided Assistance	Improvement Made
• Changing lanes on a three- or four-lane divided highway. • Passing another vehicle on a three- or four-lane divided highway • Passing another vehicle on two-lane undivided highway	Changing Lane	Flexibility of Head and neck Peripheral vision	Side View Assist (SVA) system	Assist driver to check Blind spots and signal if there are objects located in the blind spot	Increase the Frequency of checking blind spots Draw attention to approaching traffic Provide early warning on the approaching traffic
• Driving in heavy traffic	Heavy Traffic	Motion perception Contracts sensitivity	Adaptive Cruise Control (ACC)	Assist driver to control the vehicle speed according to other vehicles on the road	Draw attention to approaching traffic Assist the driver in directing his attention to relevant information
• Approaching an intersection with traffic lights • Approaching an intersection without traffic lights. • Making left turns that is not controlled by a traffic light. • Making left turns that is controlled by a traffic light.	Intersection	Selective attention	Automated Pedestrian Detecting (APD) system	Detects and alerts drivers when there is a danger of collision with a pedestrian or other objects	Assist the driver in directing his attention to relevant information Provide early warning on the approaching pedestrian Improve speed of processing information and making decisions

3.2. Questionnaire 2

After identifying older adult drivers' challenging driving situations, some in-vehicle technologies that could mitigate older adults' driving difficulties were investigated. Six in-vehicle systems that assist drivers in various driving situations were identified (Mitchell and Suen, 1997; Davidse, 2006). In the second column of Table 1, the challenging driving situations were categorized based on their similarities. Moreover, the type of support that could prevent such driving-related difficulties, and the in-vehicle technology which could provide such a support were provided in other columns.

The first selected system was the Automatic Windshield Wipers (AWW) system, adapts the speed of wipers according to the precipitation through infrared sensor detection. It could improve driving safety by allowing drivers to continue focusing on the road without being distracted by the windshield wiper speed as the precipitation increases/decreases (Young, 2014). This system could improve the speed of processing information and making decisions. The second system considered is the Night Vision Camera (NVC). This technology provides roadway information that is either difficult or impossible for the driver to obtain through direct vision, using infrared cameras to detect objects on a road. There are many studies confirmed benefits of this system in enhancing safety although not many older adult drivers used this system (Eby *et al.*, 2015). The third system considered in this study is the Lane Departure Warning (LDW) system designed to keep cars in lane. It was estimated that this system could decrease 3 percent of all crashes happened in the US (Blower, 2014). (Eby *et al.,* 2015) recommend this technology to older drivers especially to whom took medication that can cause drowsiness and to whom took long trips. The fourth was the Adaptive Cruise Control (ACC) system that could help older adult drivers by adapting their driving speed to traffic on high speed roads. This system cuts some of the driving tasks and can have a positive impact on traffic operation by directing their attention to traffic (Li *et al.,* 2016). The fifth system considered was the Side View Assist (SVA) system or Blind Spots Warning system. Lavalliere et al. (2011) in their simulator study compared blind spot checking among younger and older adult drivers and concluded that older drivers checked blind spots significantly less frequently. The authors mentioned that the system not only decreases older adult drivers' crashes, but also increases mirror checking frequency and provides prior knowledge on the next traffic situation which could promote more situational awareness. Last but not least, the Automated Pedestrian Detecting system (APD) was considered in the study. It appeared as the first in the Seven New Technologies to Help Older Drivers by Mulholland (2009). This system detects and alerts drivers when there is danger of collision with a pedestrian or other objects.

The identified in-vehicle technologies could potentially improve older adult drivers' driving safety only when they are accepted and used by older adult drivers. This study was motivated to investigate older adult drivers' acceptance of these technologies by considering a conceptual model called UESA model. This model is based on two main effective factors on user decision such as perceived usefulness and perceived ease of use (TAM) as well as perceived safety and perceived anxiety (CTAM). It is worth mentioning that since this study did not measure the variables after actual experience, the model could study only perceived use behavior. The definition of the model's dimensions is stated in table 2.

Table 2

Definition of the Conceptual Research Model Dimensions

Dimensions	Definition
Perceived Usefulness	The degree to which a driver believes that using a particular in-vehicle technology could be helpful for his/her driving performance.
Perceived Ease of Use	The degree to which a driver believes that using a particular in-vehicle technology could be used with little effort.
Perceived Safety	The degree to which a driver believes that using a particular in-vehicle technology could insure his or her well-being while driving.
Perceived Anxiety	The degree to which a driver believes that using a particular in-vehicle technology could annoy him/her.
Perceived Use Behavior	The degree to which a driver believes that he/she would use a particular in-vehicle technology.

Questionnaire 2 was developed to rate the acceptance of the selected in-vehicle technology systems based on the UESA model. After contacting the older adults who participated in the first questionnaire, questionnaire 2 was conducted in the same locations mentioned in section 3.1. The questions were categorized into 5 parts. The first 4 parts are the same as the first questionnaire. In the last part, participants were asked to rate six in-vehicle technology systems. Before being rated, each system was presented to the participants through slides, photos, and short videos. Following each presentation, based on the proposed model, participants' opinion were collected. The perceived use behavior of each systems was also rated. Participants rated each system using a 5 point Likert scale ranging from 1 (not likely) to 5 (extremely likely). All of the questions were multiple choice.

4. Results

The results were divided into two parts corresponding to the two questionnaires. Questionnaire 1 identified the driving situations that were considered challenging by older adult drivers. As the results, the assistance which older adult drivers need in those driving situation as well as the in-vehicle technologies developed to provide the assistance were determined. In order to investigate older adult drivers' acceptance regarding these in-vehicle technologies, questionnaire 2 was developed and conducted. Both questionnaires collected driving profile of participants.

4.1. Questionnaire 1

The majority of participants were recruited from three age groups, 61-70, 71-80, and 81-90 years old. Approximately 50% of them were in their 70s and 30% of them were in their 60s. 16% of participants were between 81 and 90 years old, and one participant was in his/her 90s. Five of the participants were less than 60 years old. It is noted that two-third of participants were female. All of the participants were active drivers, and the majority of the older adult drivers (42%) have held their driver's license for 51-60 years. 30% of participants have had their license for 41-50 years, 24% received their driver's license for more than 60 years, and 6 (4%) have had their license for 31-40 years. Fig. 1 shows results obtained from both questionnaires on how often and how long older adult drivers typically drive. According to the left-hand side of the figure, approximately 64% of the participants reported that they drove more than once a day. The right hand side of the figure showed about more than half of the participants responded that their drives took approximately 15-30 minutes.

One aim of the questionnaire was to map self-reported health status of participants with their driving profiles. Health concerns included 10 categories (see section 3.1). Participants could choose multiple health concerns if applicable. The results are represented on the left-hand side of Fig. 2. More than half of the participants (54%) reported having some health concerns. As shown, vision, bones and joints (flexibility), and memory were the top-rated health concerns by older adult drivers. In the questionnaire, participants were asked to report crash experiences that they had in the previous 10 years (allowed multiple choices). Overall, 94% of the participants had at least one crash experience. According to Fig. 2, most of the crash experiences occurred at snow, fog, intersections, changing lanes, night, merging into traffic and highways.

In order to understand the driving situations in which older adult drivers consider challenging or dangerous, the last part of the questionnaire asked them to rate the listed 20 specific driving situations. A 1 to 5 Likert scale allowed participants to provide a rating on these challenging and dangerous driving situations where 1 means not challenging and 5 means extremely challenging. Fig. 3 shows the average rating of challenging driving situations according to participants' ratings. Weather conditions such as snow, fog, and rain, night driving in urban and rural, unfamiliar high-speed roads, passing vehicles, heavy traffic, and changing lanes were considered more challenging driving situations (rated more than 2 in average) than others by older adult drivers.

One aim of the first questionnaire was to gain a better understanding of the relationship between driving profiles and their ratings. According to the older adult drivers' ratings, the first 13 driving situations from left on Fig. 3 were considered challenging (rated more than 2 which means somewhat challenging). These challenging situations were categorized into five groups based on their similarities: weather conditions, night driving, high-speed roads, changing lanes (or passing vehicle), and heavy traffic. The majority of older adult drivers who rated weather conditions, night driving, and changing lanes (the three top challenging situations) as challenging driving situations (more than 2) were in their 70s, and most of them were females. Most of the female older adult drivers in the 61-70 age group rated unfamiliar highways and heavy traffic as challenging. Moreover, more than half of the older adult drivers who considered these five driving situations challenging drove not more than once a week. It is worth noting that the majority of the participants' trips took less than 30 minutes. Older adult drivers who drove less frequently and for shorter lengths were more likely to consider these five driving situations challenging. In terms of health concerns, the participants who rated these five driving situations challenging typically had at least 2 health concerns.

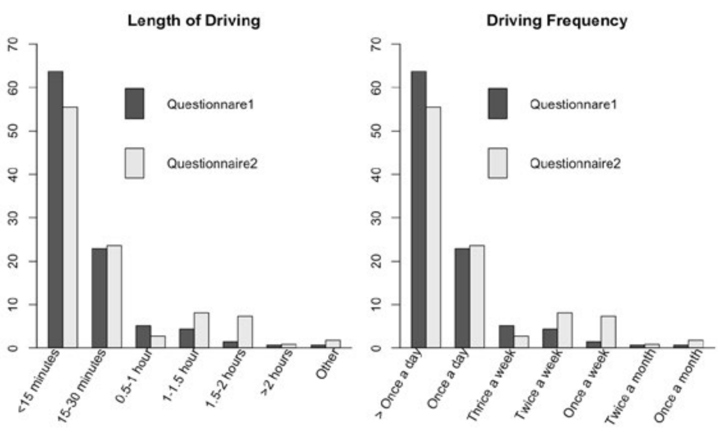

Fig. 1.
The Length and Frequency of Older Adults Driving Obtained from Both Questionnaires

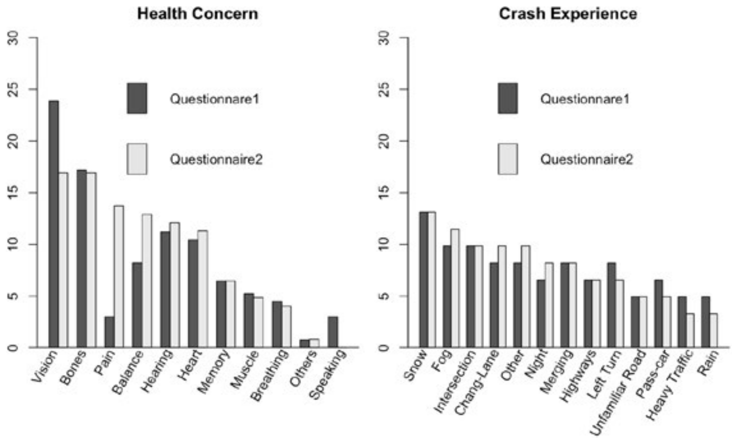

Fig. 2.
The Health Concern and Crash Experience of Older Adult Drivers Obtained from Both Questionnaires

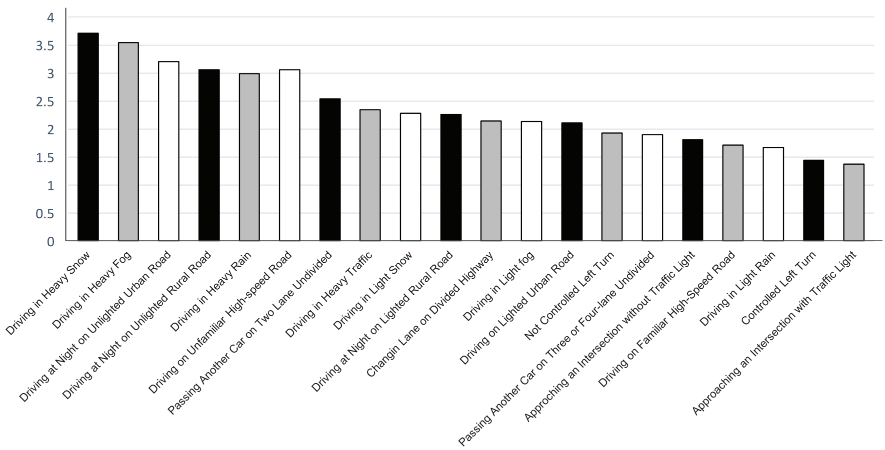

Fig. 3.
The Average Rating of Challenging Driving Situations

4.2. Questionnaire 2

As was in the case for questionnaire 1, in questionnaire 2, 95% (majority) of participants were between 61 and 90 years old. 3% and 2% of the participants were older than 90 years old and younger than 60 years old, respectively. 61% of participants were female. 35% of older adult drivers have held their driver's license for 51-60 years, 27% of participants have had their license for more than 60 years and 23% of participants have received their drivers' license between 41 and 50 years ago. There were 7 older adult drivers who had acquired their driver license less than 20 years. There were other 7 drivers who have their license for 21-30 years. Only three older adult drivers have held their license for 31-40 years.

Similar to questionnaire 1, two survey questions asked about how often and how long older adult respondents usually drove (see Fig. 1). Similar to the first questionnaire's results, more than half of them reported that they drove more than once a day and they usually drive 15-30 minutes.

Fig. 1 illustrates the percentages of reported health concerns from questionnaire 2's participants. More than half of them reported some health issues. Clearly, vision, bones, and joints (flexibility), pain, and balance were the most reported and prominent concerns of older adult drivers. These results were almost similar to health concerns results of questionnaire 1 except for vision, memory and speaking which may be more popular in questionnaire 1 and pain which is more popular in questionnaire 2. Fig. 2 represents the crash experiences on its right hand side. More than half of the responders (59%) did not have any crash experiences. But the most popular response was that crash experiences occurred due to weather conditions such as snow and fog, intersections, changing lanes, driving at night, merging into traffic and driving on highways. These results are similar to those we gained from questionnaire 1.

As mentioned, the aim of questionnaire 2 was to explore older adults' acceptance regarding the six in-vehicle technologies which aim to enhance the driving safety in the identified driving situations. Participants' acceptance was measured based on the UESA model. In addition, they were asked to rate how likely they would use the system. The Likert scale in this questionnaire ranges from 1 (not likely) to 5 (extremely likely). In this section, firstly, the study compared the six systems based on the UESA model's dimensions. Then perceived use behavior was discussed. Data were classified according to popular health concerns to see if there is any difference between perceptions of older adults with different health concerns. Subsequently, the scope was changed to look at each system individually to determine underlying structure in the UESA model results.

Table 3 illustrates the average ratings of each system based on UESA model's dimensions and perceived use behavior. According to the Analysis of Variance (ANOVA) results on multiple mean comparisons, there were significant differences between the six technologies in each dimension. In the last two columns of Table 3, F-values and P-values was reported. The SVA had the highest mean rates for perceived usefulness, perceived ease of use, and perceived safety dimensions while the AWW had the lowest mean for perceived anxiety. As above mentioned, the participants were asked if they would use (perceived use behavior) the system. According to the ANOVA results, there were significant differences between the perceived use behavior (considering all four model dimensions) of the six systems with a P-value <0.001. Drivers again rated the SVA higher among all the systems for perceived use behavior.

Table 3
Model Dimensions' Averages According to Each In-vehicle Technology and ANOVA Results

Model Dimensions	ACC	SVA	LDW	NVC	APD	AWW	F-value	P-value
Perceived usefulness	3.691	4.255	4.138	3.991	4.027	3.036	14.59	<0.001
Perceived ease of use	3.573	4.145	4.028	3.514	3.791	3.173	8.99	<0.001
Perceived anxiety	2.282	2.073	2.110	2.435	2.200	1.681	4.59	<0.001
Perceived safety	3.145	3.982	3.596	3.407	3.636	2.700	12.36	<0.001
Perceived use behavior	3.318	4.036	3.918	3.609	3.709	2.929	9.60	<0.001

In order to investigate the relationship between health concern and perceived use behaviour of different in-vehicle technologies, we next classified perceived use behavior ratings and categorized them into four different groups according to older adult drivers' health concerns (see Fig. 4) to investigate whether older adult drivers with different health concerns had different preferences about using the six systems. The first group was drivers with only vision concerns (26 responders). According to ANOVA results, perceived use behavior ratings for the six systems were not equal (P-value <0.001) and SVA had the highest mean (4.34). It is worth noting that the mean ratings for SVA perceived use behavior among drivers with vision impairments were higher than all other drivers. The second group was drivers with only memory concerns (25 responders). This second group's perceived use behavior ratings for the six systems were not equal, and SVA was rated higher than other systems with means equal to 4.08 (P-value <0.001). According to mean comparison, responders with memory concerns rated the six systems lower than all other drivers. The third group was respondents including those with multiple health concerns: bones, pain, balance, hearing, and vision concerns (27 responders). This group did not rate the systems differently. However, the means of perceived use behavior ratings of this group were higher than all other responders. Lastly, there was a group of 35 responders who do not have any health concerns. Their perceived use behavior ratings were not significantly different. However, this group's ratings for all systems was lower than those of all other drivers. It is worth noting that SVA was rated highest by healthy older adult drivers and by those with multiple health concerns.

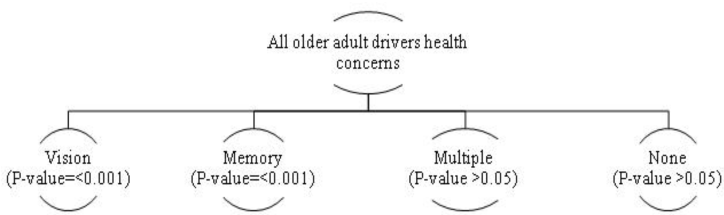

Fig. 4.
Classification Perceived Use Behavior Ratings with Respect to Drivers' Health Concern

The scope was changed to look at each system at a time. Due to correlations (>|0.7|) shown between the model dimensions and each in-vehicle technologies, Principal Component Analysis (PCA) was applied in this study. This technique derived uncorrelated linear components from the original data. The first principal component accounts for the maximum possible proportion of the variance of the original data set, and subsequent components account for the maximum proportion of the unexplained residual variance, and so forth. In fact, each of principal components are a linear combination of original variables and set of eigenvectors weights. Eq. (1) illustrates the linear models.

$$V_j = \beta_{1j}x_1 + \beta_{2j}x_2 + \cdots + \beta_{Nj}x_N = B_j^T X \quad (1)$$

V_j are the underlying linear components as a function of the original X variables such as the four model dimensions. β represents a set of eigenvector weights. The variance covariance matrix of the components would be a diagonal matrix with eigenvalues of the linear combinations along the diagonals which could be describe as (Eq. (2)):

$$S_V = B'S_xB \quad (2)$$

where: S_V is a variance covariance matrix, B is matrix of eigenvalues and B is transpose of it. S_X is the matrix of variances and covariances among the four original variables which was calculated from the following Eq. (3):

$$S_x = \frac{1}{N}\sum_{i}^{N}(X_{i}{-}\bar{X})(X_{i}{-}\bar{X})^T \quad (3)$$

To distinct between the model dimensions, the principal component analysis (PCA) was conducted. Based on Harlow (2014) recommendation, the scree plot could be considered as one way of assessing the number of components. This plot, which is introduced by Cattell (1966), has the number of eigenvalues on Y-axis and maximum number of dimensions on the X-axis. The point at which eigenvalues drop off to insignificant size is estimation for the number of underlying components. Fig. 5 provides the scree plot for the all six in-vehicle technologies. As you can see, after two components, the eigenvalues size drop. AWW is an exception in which the drop happened after first one component.

Another way of look at PCA is by examining the eigenvalues and the percentage of variance explained. Table 4 reports the explained variance percentage and cumulative percentage of the components for each in-vehicle technology. As noted, the first component explained more than half of the variance. According to Harlow's (2014) recommendation, it would be reasonable to consider the number of component which explain 50 percent or more of variance. To follow the recommendation, the second component should not be added.

Table 5 shows the orthogonally rotated loadings from PCA of the the UESA model for each of the in-vehicle technology. Perceived usefulness, perceived ease of use, and perceived safety show loadings greater than 0.52, indicating a clear component structure for this construct. The loading for perceived anxiety is higher (>0.990) in the second component. In this study, an oblique Promax rotation is also conducted. The results revealed similar pattern of PCA loadings.

Using the PCA uncorrelated linear components derived from the original data. The first principal component accounts for the maximum possible proportion (more than half) of the variance of the original data set. Perceived usefulness, perceived ease of use and perceived safety were the UESA model dimensions which have high loadings for this component.

5. Discussion and Conclusion

As the population of older adults in developed countries continues to grow, particularly due to the "baby boom" generation, concerns about the safety of older adult drivers and those who share the road with them have increased. Through the two employed questionnaires, possible situations that lead crashes to occur and technology solutions that could improve older adult driving safety were identified.

According to the results obtained from the first questionnaire, like other self-reported and subjective studies (Charlton *et al.,* 2006; Levin *et al.,* 2012; Henriksson *et al.,* 2014), this study found that older adult drivers identified weather condition, night and high-speed roads as challenging driving situations. Although participated Rhode Island older adult drivers have seasonal weather conditions experience, they mentioned that weather conditions as the most challenging driving situation. The other key finding was that drivers who drove less frequently rated the top three mentioned challenging driving situations higher.

After identifying challenging driving situations for older adult drivers, six in-vehicle technologies which could mitigated challenges were identified. In regards to investigating older adult technology acceptance, a four dimensional model was considered in this study. According to the principle component analysis, perceived usefulness, perceived ease to use, and perceived safety were constructed underlying dimensions which explains most of the variability in rating of all six in-vehicle technologies.

The other finding from the second questionnaire is that the Side View Assist (SVA) system was found as the best acceptable in-vehicle technology for older adult drivers. This system was rated significantly higher than others. This system could help increase the frequency of checking blind spots, draw attention to approaching traffic and provide early warning on approaching traffic. As a results, it could decrease older adult drivers' crash risk (Census, 2013). In addition, due to vision and attention supports provided by this system, the older drivers who are vision and memory impaired significantly rated this technology higher than others. It's worth mentioning that older adult drivers with multiple health concerns reported being more likely to use the in-vehicle technologies than other older adult drivers.

The result of this study could help us gain a better understanding of older adults' driving challenges and their acceptance and potential usage of in-vehicle technological solutions. The authors plan to conduct a nationwide questionnaire in a future study to assess older adults across the nation regarding their driving challenge concerns and means to ease these concerns. Moreover, future research needed to conduct empirical study in actual car environment and include other dimensions to the conceptual research model.

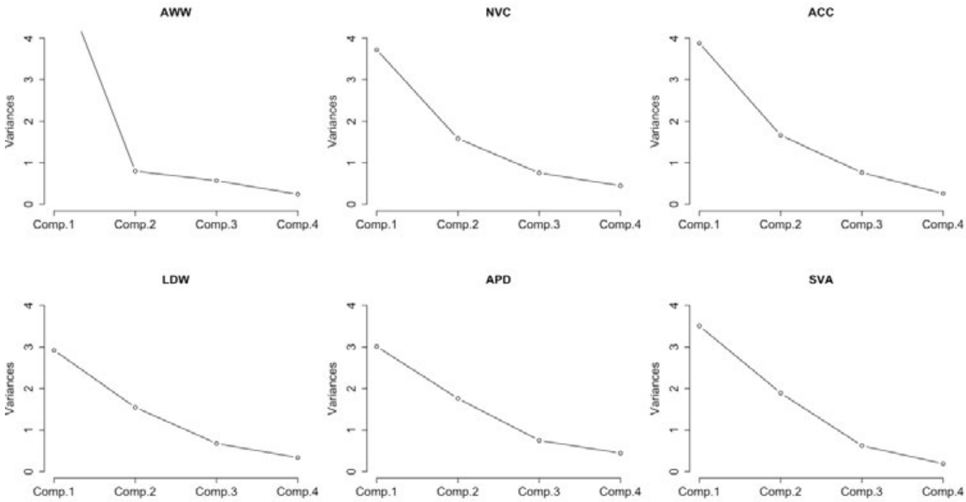

Fig. 5.
Screen Plot for the Six In-vehicle Technology

Table 4
Percentage Variance and Cumulative

	ACC		SVA		LDW		APD		NVC		AWW	
	Var. %	Cum. %	Var. %	Cum. %	Var. %	Cum. %	Var. %	Cum. %	Var. %	Cum. %	Var. %	Cum. %
Comp. 1	0.591	0.591	0.564	0.564	0.560	0.560	0.538	0.538	0.566	0.566	0.707	0.707
Comp. 2	0.253	0.844	0.304	0.868	0.248	0.808	0.252	0.800	0.251	0.817	0.199	0.906
Comp. 3	0.116	0.960	0.100	0.968	0.119	0.927	0.127	0.917	0.113	0.930	0.064	0.970
Comp. 4	0.040	1.000	0.032	1.000	0.073	1.000	0.083	1.000	0.070	1.000	0.030	1.000

Table 5
Varimax Rotated PCA Loading Matrix for the UESA Model of Six In-vehicle Technology

	ACC		SVA		LDW		APD		NVC		AWW	
	Comp.1	Comp.2	Comp.1	Comp.2	Comp.1	Comp.2	Comp.1	Comp.2	Comp.1	Comp.2	Comp.1	Comp.2
Perceived Usefulness	0.592	<0.1	0.576	<0.1	0.554	<0.1	0.551	0.120	0.593	<0.1	0.566	0.118
Perceived Ease of Use	0.551	<0.1	0.558	<0.1	0.527	<0.1	0.582	<0.1	0.553	<0.1	0.532	0.232
Perceived Safety	0.578	<0.1	0.597	<0.1	0.633	<0.1	0.589	<0.1	0.585	<0.1	0.543	0.197
Perceived Anxiety	<0.1	0.991	<0.1	1.000	<0.1	0.990	0.109	0.990	<0.1	0.995	<0.1	0.944

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