Exploring challenges in developing a smart and effective assistive system for improving the experience of the elderly drivers

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Abstract: *Driving-related injuries associated with elderly drivers are on the rise although the overall rate of driving-related injuries has been decreased. To address how the increasing accident rates have become problem worldwide, the higher injury rates among elderly drivers from different regions are introduced. Then, this paper explores existing vehicle systems that use smart vehicle technologies to promote safe driving and analyses their limitations on utility, since current systems are not created by people with driving difficulties caused by health problems, which in turn often afflict the elderly. Moreover, based on elderly drivers with declining body conditions, a survey is used to discover the problems they encounter while driving and demonstrates how new system concepts can be developed for the elderly. Finally, this paper proposes integrated utility-based solutions for the elderly that can provide a more enjoyable driving environment for this population.*

1 Introduction

Population aging is rapidly becoming a global phenomenon. According to the United Nations 'World Population Aging' report (2013), "The number of elderly aged 60 years or over were about 202 million in 1950, has accelerated to 841 million in 2013, and will triple by 2050." Given the increasing age of the Earth's population, the elderly group has become a socially and economically sector offering us both opportunities and challenges on the various aspects of daily living and health management. In particular, the automotive industry has faced diverse challenges related to the safety of the elderly. Driving-related injuries associated with elderly drivers are on the rise worldwide, while the overall rate of driving-related injuries has decreased. The National Highway Traffic Safety Administration (2014) reported in 2012 that there were 5,560 people 65 and older killed and 214,000 injured in motor vehicle traffic crashes in the U.S. These older people made up 17 percent of all traffic fatalities and 9 percent of all people injured in traffic crashes during the year. Additionally, in 2012, elderly drivers, who are defined as those 65 and up, were involved in 102,997 accidents nationwide — up from 83,058 in 2002 (Institute for Traffic Accident Research and Data Analysis, 2012).

Given this fact, we have found one of the reasons for the higher injury rate in the elderly is that current vehicle systems have not considered the body conditions afflicting the elderly, such as decreased vision, hearing, and slow reaction times, for system designs and developments. Specifically, many studies into automotive system development have noted that vehicle developers have ignored how each age group understands the system information differently and the perceptions and driving behaviours can be strongly influenced by declining health conditions. In fact, a lot of elderly drivers complain about distractions during driving due to the complex systems, and in 2014, the National Highway Traffic Safety Administration (NHTSA, 2014) reported a spike in motor vehicle crashes to more than 3,300 deaths on U.S. roadways – which can be attributed to driver distraction issues. This proves that current vehicle systems are not practical enough for elderly drivers to operate easily and there is no benefit with highly technological diverse safety systems. However, only a few scholars have noted that declining health conditions affect how elderly drivers interact with in-vehicle systems. Thus, it is important to integrate the elderly users' abilities and needs into system design and development approaches in order to protect them from fatal accidents and provide a safe driving environment on the road. In a boarder term, this indicates a need to develop a smart automotive product/system for better user experience, which adds an additional level to autonomous cars (Tefft, 2008).

With the significance of in-vehicle systems for elderly drivers, this paper first introduces some factual data concerning increasing accident rates for elderly drivers worldwide – Asia, Europe, and North America – to emphasize how fatal accidents have become a serious problem over the world for senior citizens and then understand why developing a smart and effective system could be a new challenge for the automotive industry. Furthermore, a different set of systems developed from current studies for elderly drivers are explored and analysed to investigate the challenges of change in the automotive system. Moreover, this paper clarifies the difficulties and behaviours experiences by elderly people in different driving situations with diverse research activities like survey and interviews. Finally, this paper suggests diverse possible solutions for developing such a smart system design such as technology driven, user need basis, and market driven solutions as a new challenge for the future in-vehicle system of the elderly drivers.

2 Problem: Impact of road traffic accidents on the elderly

With the growing number of elderly drivers, their accident rates on the road have been dramatically increasing all over the world. The higher injury rates among elderly drivers from different regions, such as America, Europe, and Asia are introduced to elicit how the increasing accident rates have become a problem in many countries.

2.1 North America

The data of the U.S.A and Canada are introduced. Since driving for mobility is mandatory for people who live in a large continent, elderly drivers tend to drive there more than in other regions. In the United States, traffic injuries among the elderly are becoming a serious social problem from diverse data reported. According to the National Highway Traffic Safety Administration (NHTSA, 2014), 36.8 million licensed drivers were age 65 and older in the United States in 2013. By 2020, there will be more than 40 million drivers on the road in this age group. The NHTSA says 5,671 people age 65 and older were killed in traffic crashes in 2013. This represents 17 percent of all Americans killed on the road. In addition, 222,000 older individuals were injured in traffic crashes in 2013. Even in the past, according to data from the NHTSA (2011), in 2009, 5,288 people age 65 and older were killed and 187,000 were injured in traffic crashes. They accounted for 16 percent of all traffic deaths and 8 percent of the injured, but they accounted for 13 percent of the population. The report said the number of deaths among drivers age 65 and older grew to 5,750 in 2010.

Also, Canada's data for the elderly's accidents showed high rates like the US. According to Transport Canada (2007), seniors aged 65 and older accounted for the second largest proportion of road deaths in Canada, at 16% (or 462 road fatalities) and also accounted for 7.8% (15,545) of injuries in 2006. Only youths aged 15–24 accounted for a larger proportion of deaths, at 24.7%. Moreover, Canadian seniors have the second highest motor vehicle death rate among licensed drivers, with an average of 15.7 deaths per 100,000 licensed drivers, compared to 24.7 deaths for drivers aged 15–24, and 9.6 deaths for drivers aged 25–64 (Johnson & Howard, 2007). In general population terms, the trend is less pronounced: in 2006, elderly drivers in Canada had fatality rates of 10.7 deaths per 100,000 population, compared to 16.9 for youths aged 15–24, and 9 for adults aged 25–64 (Lécuyer & Chouinard, 2006). Thus, Canadian seniors have road death rates that are elevated relative to their representation in the general population and the population of licensed drivers—this is a concern from a public health perspective, regardless of the question of whether seniors are more or less often responsible for causing these crashes.

2.2 Europe

Elderly drivers in Europe now represent the most rapidly growing segment of traffic accidents. For example, in the United Kingdom in 2008, 190 drivers over the age of 60 were killed in road accidents, 1,148 were seriously injured, and 9,677 were slightly injured. Although the casualty trend is decreasing, it is decreasing at a slower rate than that of other age groups. Reported statistics indicate that the risk of being involved in an accident increases after the age of 70, and drivers over 70 and especially over 80 years are more likely to be at fault when they crash with other cars (Department for Transport, 2011). Also, in Germany, people 65 years old and older constitute 20 percent of the population, but make up 27 percent of all traffic fatalities. A study by the German Consumer Association showed an injury risk that is 14 percent higher for the age group over 55 years old in comparison to people 18 to 35 years old (Otte & Wiese, 2012).

2.3 Asia

South Korea and Japan have the same critical issues. South Korea became an aging society in 2000. Consequently, the high injury rate of the elderly in motor vehicle crashes is a serious concern. According to the Traffic Accident Statistics in 2009, 1,735 people age 65 and older were killed in 2008, and these older individuals made up 29.6 percent of all traffic fatalities (S. W. Hong, Park, & S. Hong, 2013). Compared to 2007, all accidents increased by 2.0 percent, but the accidents involving elderly people increased by 8.9 percent. Among people injured in this age group, there was an 8.9 percent increase from 2007 (Hong et al., 2013). In the case of Japan, while the number of young driving-license holders below 24 years of age gradually decreased, the number of elderly license holders aged 65 or older increased (Morita & Sekine, 2013). In 2012, elderly drivers, who are defined as those 65 and up, were involved in 102,997 accidents nationwide — up from 83,058 in 2002 (Institute for Traffic Accident Research and Data Analysis, 2012, para. 2). Moreover, 70 percent of

the 447 accidents were attributed to vision and hearing issues of drivers aged 65 or over (Jie & Horie, 2013).

All countries showed a higher injury rate in elderly than younger drivers. Particularly, South Korea showed a high growing rate of 8.9 % in fatal accidents for elderly citizens. In the US and Germany, the fatal collisions rate of elderly drivers is 14~17% higher than young drivers. In Japan, most accidents caused by the elderly are due to impaired vision and hearing. This proves that there is a strong relationship between the higher accident rates and the user segment- elderly. Additionally, many studies and researchers propose that such trends will continue. Thus, it is necessary to understand how their aging health conditions affect their driving ability and to suggest practical recommendations to minimize the elderly's fatal accidents. In 2008, 190 drivers over the age of 60 were killed in road accidents, 1,148 were seriously injured, and 9,677 were slightly injured. Although the casualty trend is decreasing, it is decreasing slower than that of other age groups. Reported statistics indicate that the risk of being involved in an accident increases after the age of 70, and drivers over 70 and especially over 80 years are more likely to be at fault when they crash with other cars.

3 Smart vehicle technology-based solutions

Many studies have been carried out for elderly drivers and have raised the issue that the elderly's fatal accidents rates have been increasing globally. Current studies have proposed some systems for safe driving for this population based on smart technology. In this section, we first describe the exemplar systems as solutions for mitigating the elderly's accidents on the road and then analyse their effectiveness or utility.

3.1 A new mobile phone-based safety support system for elderly drivers

This study (Matsuoka et al., 2011) had been processed to help elderly people who have dementia, and who have many behaviour disorders such as wandering, poor verbal communication and being uncooperative. Their wandering behaviours are a major cause of road deaths. Thus, this study had developed a safety support system for wandering elderly drivers on the road by detecting their location and situation. This system consists of a wearable sensor and a conventional desktop PC with internet access acting as the server computer. When the elderly drivers use the system, they have to install the wearable sensor, attached behind the neck of the elderly person's shirt. It has a low transmitting power mobile phone, which is called as W-SIM, a small microphone, and a chip microcontroller. The wandering elderly driver's location is identified within 100m from the mobile phone company's antenna ID through the W-SIM. Other people who are looking for or caring for the elderly drivers could set the elderly's movement by specialised computer software (2011). When the elderly person goes out, the sensor automatically records the environmental sound around the wandering elderly person. Both the wandering elderly person's location and environmental sound are sent to the server computer automatically. The server computer receives the latitude and longitude data of the location from the W-SIM via Internet, and then the data is stored by the server computer and automatically informs other people via email. In this study (2011), most elderly drivers are rescued by other people within 20 minutes when they lost their way. Since elderly people forget driving methods easily due to disrupted memory, this system is expected to help those with cognitive impairment.

3.2 Head-up display (HUD)

Charisis et al. (2011) developed an interface system, named for Head-Up Display (HUD) in their study. This system mainly provides crucial information to the driver in a timely manner for mitigating elderly's collisions on the road. This interface system comprises symbolic representation of the lead vehicles and road information acting as a vision enhancement system. Elderly drivers suffer more from slower response times than other groups of drivers, due to their declining sensory functions and

reflexes. Also, current complex roadway conditions, adverse weather conditions, and unexpected traffic congestion could be a main factor for slower reactions in elderly drivers causing collisions and resultant fatalities. Thus, this study (2011) developed a full windshield Head-Up Display (HUD) interface for offering elderly drivers crucial collision avoidance information by improving the driver's spatial awareness and response times under low visibility conditions. The information was delivered to the users in the following way.

A pathway symbol represents the lane borders and alters the colour depending on the sensing of vehicles on each side, providing a clear warning for blind spots. The lead vehicle's symbols are designed to highlight the first row of leading vehicles. The vehicle in the same lane with the user is additionally noted with an inverted triangle. Also, a traffic symbol appears in the top of the windshield spotting any potential traffic flow bottlenecks (Charisis et al., 2011). The interface concludes with the turn symbol which acts as an early warning for sharp and potentially unnoticeable roadways, such as curves and rough road (2011). In their research, the system simulation test was conducted with 40 users, age-ranged between 20-75 and its main simulation scenario was users under a typical rear-collision accident situation using the HUD interface (2011). This test challenges the reflexes and decision making of the driver on a motorway stretch between Glasgow and Edinburgh. The test weather condition was hazy due to simulated dense fog that creates zero visibility conditions (2011). From the simulation test, the elderly users presented a significant improvement on their response times when using the HUD system which reflected as decreased collisions or low impact collisions in comparison to their performance with the use of the typical dashboard information (2011).

3.3 Foot-LITE System

The Foot-LITE system was a research project developed by the UK Engineering and Physical Sciences Research Council, and targets drivers from across the socio-economic spectrum and at all levels of experience, making it an appropriate system for use by elderly drivers (Fairchild et al., 2009). It is composed of an in-vehicle device to provide immediate feedback to the driver on a full colour screen that indicates the driving error or risky behaviour that has occurred and provides support showing how it may be corrected and avoided in the future (2009).

This system works with the following feedback. First, further in-vehicle feedback is provided at the end of a trip, indicating journey length, cost that is measured by the fuel used, and emissions (Fairchild et al., 2009). Second, it offers support in the form of lessons to be learned (2009). Finally, statements sent out through the internet at the users' pre-set timing, like weekly or monthly, provide totals of measured driving factors such as fuel consumption or the number of times a driving infringement was committed for that time period and also provides a comparison of how the driver is performing in terms of the changes that have been made in driving style and their impact on the cost of driving and vehicle emissions over a longer period of time which encompasses multiple trips (2014). Lastly, off-vehicle web-based support directs the driver to personalized lessons that will show them how to improve their driving style (2009).
With the feedback flow, this system will deliver valuable information to elderly drivers to promote the take-up and retention of appropriate eco-friendly, safe, and efficient driver behaviours.

With the system, elderly drivers can efficiently drive on the road before and during their trip by having diverse information from the road network and selecting alternative routing that avoids traffic congestion and revises trip routes. If elderly drivers use the system, their accidents would be expected to decrease. If they get information from the road network set-up for the Foot-LITE system before their trip, they can avoid congestion and can spend longer time on the road. Thus, they could prevent accidents due to less fatigue from a shorter time driving.

3.4 Discussion on the existing studies

Such systems developed from current studies are in constant development. Introduced systems in the studies are meaningful because the systems were developed to specifically target elderly drivers. Most of the studies have just tried to find beneficial aspects for the elderly drivers from the systems.

However, the development and testing of these studies tend to be focused on the driving population as a whole rather than the specific needs of elderly drivers , though many studies have discovered diverse ways to support elderly's safety on the road. Thus, there are still some drawbacks in each system when used by the elderly.

For example, a new mobile phone-based safety support system could not be useful to find the elderly drivers' locations when they plan a long drive or new destinations since this system sensor relies on the environmental sound that the elderly is usually in. Also, if the elderly's locations are very quiet, it becomes difficult to presume the locations because a characteristic sound around the locations cannot be recorded by the system sensor. In fact, in the system study, the accuracy of the location around a park area was considerably less than a general GPS system.

While the HUD interface system doesn't guarantee prevention of the elderly driver collisions because some collisions occurred even at very slow response times during the system test. Although the system indicates potential collisions with different visual cues to the elderly drivers, this does not address those with visual problems. Since elderly drivers can't easily recognise diverse colours, they might not react properly when the visual symbols appear as a warning signal. From the study, researchers mentioned that the sudden induction of a colour-changing pattern to the driver's field of view can cause unexpected reactions. Such colour changes could distract the elderly drivers more rather than help them easily recognise the visual warning cues.

As for the Foot-LITE interface system, it focuses on elderly's eco-friendly and efficient driving life more than addressing their declining body conditions for the system. Thus, while the system helps the elderly with more efficient driving time by avoiding roadway congestion, it doesn't seem to be beneficial for the safer driving actions.

Given the above analysis, it can be concluded that the current studies have shown that usability for the elderly has not really been considered. Some might think that if we apply all the technologies to a new vehicle system for the target, elderly drivers, even including all the driving users could be beneficial enough from the new system.

4 Further explorations of utility based solutions

4.1 Methodology

To find more useful solutions for elderly drivers, the elderly group's survey was utilized, since it provided a more direct method for data collection. The first step involved the development of the survey content. The survey was divided into the two sections each addressing a specific area of concern. The first section included background information and medical history of the elderly participants to provide a database of the socioeconomic and health attributes. During the survey section, their background and medical information (Table 1) was requested to determine if there were any other conditions that might be affecting their driving such as any sensory loss. The second section (Table 2) included questions regarding the elderly's specific behaviours in the different driving situations and the relationship with their health conditions. Specifically, the survey questionnaires were created based on the Manchester Driver Behaviour Questionnaire (DBQ), which is a widely used instrument for measuring self-reported driving behaviour. From the two survey sections, six questions were given to the elderly participants and these questions varied between multiple choices and ranking questions on a scale of 1 to 5.

The questionnaire requirements were that participants should over the age of 55 and have a valid driver's licence and the questionnaires were distributed to elderly people in the different countries via email, such as South Korea, US and UK in order to see if they have different difficulties and behaviours in driving. Once the surveys were returned, the data was ready to be analysed. Since the purpose of the activity was to suggest better solutions to elderly drivers based on their specific driving behaviours and difficulties, the databased results will be analysed first, and the data comparison with other elderly studies were conducted (presented in the discussion section). Also, face-to-face interviews were conducted with interviewees in order to understand more for the survey result, and

the interviewees were randomly selected from the survey participants. The interview results are explained in the result and discussion sections.

4.2 Results

The first section of the survey was used to gain data based on the participants' characteristics. The second section was used to determine an accurate picture of the driving patterns and the relationship of the elderly's health and the driving from the respondents.

The first section of the survey was intended to gain some background information of the elderly drivers. The 60 participants were divided into four age groups: 1) 50-55 years old, 1) 55-60 years old, 2) 60-65 years old, 3) 65-70 years old, and 4) above 70 years. Each group had 20 participants and average group of the participants was between ages 66 and 70. A majority of the elderly drivers claim to drive 1-3 times a week, with the South Korean elderly group shows the highest rate from the driving time. The frequency of driving per week indicates that 51.7% of the respondents drive at least 1-3 times, 33.3% of 3-6 times, and 8.3% drive daily. Only 6.7% of respondents reported "Never drive." The US elderly group tend to drive more on a daily basis than other countries and all the participants from the country drive at least more than once a week due to no response to the answer, "Never driving," while the elderly respondents from South Korea and UK show 15 and 5 percentages for the same question. Also, the highest rate of the average driving time is 30 minutes to 1 hour. However, while the respondents from UK (45%) and South Korea (50%) tend to drive for the average time, US respondents (60%) tend to drive 1 and 2 hours. For the medical background from the respondents, of the 60 respondents, 100 % reported having age-related health conditions with most of them stating they have vision impairment.

Table 1. Survey Section 1 Result – The elderly's driving information

Survey Section 1			
Q1	How many times do you drive per week?		
	① 0	② 1-3 times	③ 3-6 times	④ Everyday
US	0	7 (35%)	10 (50%)	3 (15%)
UK	1 (5%)	11 (55%)	7 (35%)	1 (5%)
South Korea	3 (15%)	13 (65%)	3 (15%)	1 (5%)
Total (% of 60)	4 (6.7%)	31 (51.7%)	20 (33.3%)	5 (8.3%)
Q2	What is your average time per driving?		
	① Below 30 minutes	② 30 minutes to 1 hour	③ 1 to 2 hours	④ Over 2 hours
US	0	5 (25%)	12 (60%)	3 (15%)
UK	1 (5%)	9 (45%)	7 (35%)	3 (15%)
South Korea	2 (10%)	10 (50%)	4 (20%)	4 (20%)
Total (% of 60)	3 (5%)	24 (40%)	23 (38.3%)	10 (16.7%)
Q3	What kinds of age-related health conditions do you have?		
US	① Vision Impairment	② Arthritis, Low reaction	③ Hearing Problem	④ Hearing Problem
UK	① Vision Impairment	② Arthritis, Low reaction	③ Low Memory	④ Low Memory
South Korea	① Vision Impairment	② Low Memory	③ Low reaction	④ Hearing Problem

From the second section, the elderly driving behaviours and difficulties were evaluated. 45% reported tired eyes occurred as the first symptom after starting driving and neck and shoulder pain was reported in 25% of responses. Most elderly respondents from all countries reported feeling afraid when they drive. But, more than half of the respondents (55%) from the US do not feel nervous in their driving. The main reason for the nervousness is reduced sight with 58.3% of all respondents and the second reason is slow body movement, indicated by 25 % of them. From the list of the driving patterns and difficulties, difficulty in driving at night was reported most with a mean value = 5 and 267 scores, the second difficulty is entering the wrong lane when approaching a roundabout or a junction, and the third is to misread the signs and exits from a roundabout to the wrong road. The other listed driving patterns do not show a big difference with the top rated as shown in figure 1. However, while the overall rating results are shown in the figure, ranking varied by different regions.

US respondents rated the driving pattern, "Fail to check your rear-mirror before pulling out or changing lanes," higher than misreading signs and Korean respondents ranked higher applying sudden brakes on a slippery road, or steering the wrong way in a skid than misreading signs. The other listed driving patterns do not show a big difference.

Survey Section 2				
Q1	**What is the first symptom after starting driving?**			
	① Tired eyes	② Neck pain	③ Shoulder pain	④ Headache
US	9 (45%)	6 (30%)	3 (15%)	2 (10%)
UK	8 (40%)	4 (20%)	8 (40%)	0
South Korea	10 (50%)	5 (25%)	4 (20%)	1 (5%)
Total (% of 60)	27 (45%)	15 (25%)	15 (25%)	3 (5%)
Q2	**Do you feel afraid when you drive?**			
	① Yes		② No	
US	9 (45%)		11 (55%)	
UK	14 (70%)		6 (30%)	
South Korea	13 (65%)		7 (35%)	
Total (% of 60)	36 (60%)		24 (40%)	
Q3	**If yes, what makes you nervous to drive?**			
	① Low eyesight	② Slow body movement	③ Decreased hearing	④ Low memory
US	7 (78%)	2 (22%)	0	0
UK	6 (40%)	5 (33.3%)	1 (6.7%)	3 (20%)
South Korea	8 (61.5%)	2 (15.4%)	1 (7.7%)	2 (15.4%)
Total (% of 60)	21 (56.8%)	9 (33.3%)	2 (5.4)	5 (13.5%)
Q4	**What kind of driving patterns and difficulties do you have? Please, rate each list.**			
	Drive especially close to the car in front as a signal to its driver to go faster or get out of the way		1 (Easy) ~ 5 (Difficult)	
	Get involved with unofficial 'races' with other drivers		1 (Easy) ~ 5 (Difficult)	
	Attempt to overtake someone that you had not noticed to be signalling a left/right turn		1 (Easy) ~ 5 (Difficult)	
	Fail to notice that pedestrians are crossing when turning into a side street from a main road		1 (Easy) ~ 5 (Difficult)	
	Fail to check your rear-view mirror before pulling out or changing lanes		1 (Easy) ~ 5 (Difficult)	
	Fail to control merging into traffic		1 (Easy) ~ 5 (Difficult)	
	Take a long time to pass through an intersection		1 (Easy) ~ 5 (Difficult)	
	Apply sudden brakes on a slippery road, or steer wrong way in a skid		1 (Easy) ~ 5 (Difficult)	
	Get into the wrong lane when approaching a roundabout or a junction		1 (Easy) ~ 5 (Difficult)	
	Misread the signs and exit from the roundabout on the wrong road		1 (Easy) ~ 5 (Difficult)	
	Forget where you left your car in the car park		1 (Easy) ~ 5 (Difficult)	
	Drive away from the traffic lights feel more nervous to drive at night		1 (Easy) ~ 5 (Difficult)	
	Switch on another thing, when you intend to switch on something else		1 (Easy) ~ 5 (Difficult)	
Q5	**Do you agree that your age-related health condition caused a driving difficulty or an accident on the road?**			
	① Yes		② No	
US	11 (55%)		9 (45%)	
UK	13 (65%)		7 (35%)	
South Korea	14 (70%)		6 (30%)	
Total (% of 60)	38 (63%)		22 (37%)	
Q6	**Do you agree that current vehicle systems specifically consider elderly group's conditions and make you drive with confidence on the road?**			
	① Yes		② No	
US			20	
UK			20	
South Korea			20	
Total (% of 60)			60 (100%)	

9

Table 2. Survey Section 2 Result – Elderly's driving difficulties and behaviours

	Behaviour 1	Behaviour 2	Behaviour 3	Behaviour 4	Behaviour 5	Behaviour 6	Behaviour 7	Behaviour 8	Behaviour 9	Behaviour 10	Behaviour 11	Behaviour 12	Behaviour 13
25%	2	2	2	1	2	1	1	1	3	3	1	4	2
MIN	1	1	1	1	1	1	1	1	2	2	1	2	1
50th (MEAN)	3	3	3	3	3	3	3	4	4	3	3	5	3
MAX	5	4	4	4	5	4	5	5	5	5	4	5	5
75%	3	3	3	3	3	3	3	5	4	3	5	3

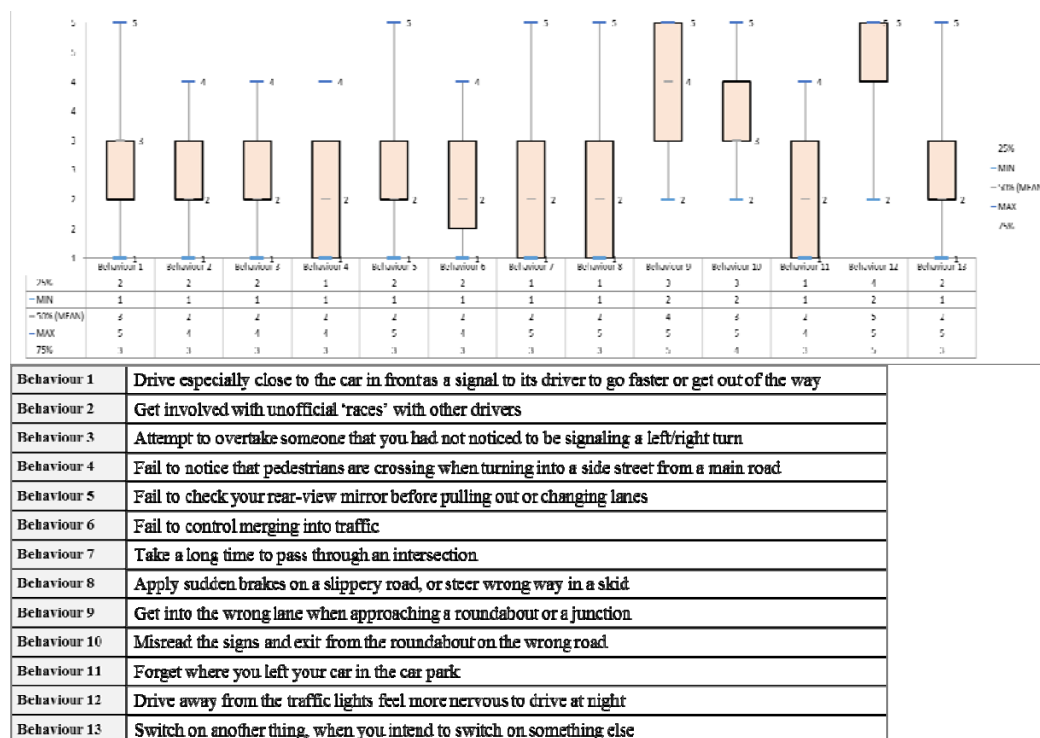| Behaviour 1	Drive especially close to the car in front as a signal to its driver to go faster or get out of the way
Behaviour 2	Get involved with unofficial 'races' with other drivers
Behaviour 3	Attempt to overtake someone that you had not noticed to be signaling a left/right turn
Behaviour 4	Fail to notice that pedestrians are crossing when turning into a side street from a main road
Behaviour 5	Fail to check your rear-view mirror before pulling out or changing lanes
Behaviour 6	Fail to control merging into traffic
Behaviour 7	Take a long time to pass through an intersection
Behaviour 8	Apply sudden brakes on a slippery road, or steer wrong way in a skid
Behaviour 9	Get into the wrong lane when approaching a roundabout or a junction
Behaviour 10	Misread the signs and exit from the roundabout on the wrong road
Behaviour 11	Forget where you left your car in the car park
Behaviour 12	Drive away from the traffic lights feel more nervous to drive at night
Behaviour 13	Switch on another thing, when you intend to switch on something else

Figure 1.Evaluation results for the elderly driving behaviours and difficulties

4.3 Discussion on the results

From the results, several points can be discussed. First, the survey section 1 showed the elderly's driving frequency and time - Driving 1-3 times a week and an average of 30 minutes to 1 hour per driving session. The respondents stated that their driving frequency and time have been reduced compared with the past and that they have become unconfident due to their aging body conditions. There might be different factors for the reduced driving frequency and time. First, since most of them are retired from their work, they have become inactive in their lives. Also, as they stated in the survey, their declining health conditions affected the result. In contrast, U.S respondents drive more frequently than other respondents and reported driving 3-5 times per week. This different result can be due to their different context. Since the majority of respondents in the other countries live in metropolitan city areas, most of them do not need self-driving for their mobility. However, since the US is a big continent, with less public transport options, self-driving is necessary for their mobility. According to the study of traffic manoeuvres of the elderly from Mitchell and Stamatiadis (2002), their respondents in the US showed that 89% of the respondents drive daily and 11 % drive weekly and even some indicated that they drive monthly. The study was conducted in a Kentucky suburb where driving is a necessity for mobility. Alvarez et al. (2008) also stated in their research about fitness to drive assessments that at the age-range group of drivers aged 75 or more, 39 out of 85 drivers (46.4%) who drove less than 3000 km per year had an illness that potentially impairs driving performance and were rated as "fit to drive with restrictions." This study stated that the medical condition of older drivers results in their lower mileage. Koppel et al. (2011) also reviewed the issues for and against mandatory age-based assessment of older drivers, and they found that there is an age-related decline in sensory, physical and cognitive areas related to driving, as well as the underlying medical conditions, with substantial individual differences existing.

Given the study results, we could assume that instances of driving of the elderly respondents could be associated with their health condition because all of them responded "Yes" to the survey questionnaire of whether they have age-related health conditions. However, since we examined with limited respondents who mostly have vision impairment and lower reaction times in their health

conditions, our future studies should perhaps focus on medical impairments related to broader health conditions, such as mental functioning, which are expected to have a greater impact on driving performance of the elderly.

From the second section, we have focused on the findings of the elderly's difficulties and behaviours in driving. First, vision problems can be a main factor as in the first section of the survey, they also responded that they have the highest declining health condition in vision. The majority of the studies related to the elderly drivers stated that when they have vision impairment symptoms, they avoid driving. Also, Lyman et al (2001) reported the relationship between driving difficulty and habits in older drivers via interviews and survey questionnaire that subjects with driving difficulties were significantly more likely to have near vision impairment. Moreover, Middleton and West Wood (2001) found in their study for the older driver requirements that it is widely considered that 85-90% of the demand of the driving task is visual in nature, and many older adults have deficits in visual function. Thus, it should be noted that an assistive system should support the elderly's visual modality the most.

From the detailed rating result of the elderly's driving behaviours and difficulties, the elderly's vision problem seems to affect the result because the highest ranked behaviours are night driving and misreading the signs. Some research evidence supports this speculation. One case study from Mitchell and Stamatiadis (2002) reviewed traffic manoeuvres of elderly and specifically chose typical elderly driving manoeuvres, such as merging situations, lane changes, night driving, and left turn manoeuvres. The study also said that many of the elderly drivers have problems with their vision, especially at night. The statistical tests of these questions showed that 15% of respondents indicated that they don't drive at night anymore on a regular basis and a significant portion, 68%, also responded that they feel increased apprehension or nervousness while driving at night. Most traffic manoeuvres have become problematic when it is dark at night. However, while our study evaluated the night driving as the most serious problem, the study research from Mitchell and Stamatiadis (2002) had a different result. The results from the lane changing section indicate that the presence of multiple vehicles on the roadway seems to be the most difficult situation for the respondents as they evaluated this difficulty in the related questions. This study also showed left-turn manoeuvres as the second most problematic– 49.3 % of respondents reported difficulty in turning left onto a busy street and merging manoeuvres, while our survey study showed a lower score.

Another case study by Parker et al (2000) involving elderly drivers and their accidents, they conducted similar survey activities to find the main types of driving behaviours and used the Manchester Driver Behaviour Questionnaire (DBQ) as we referred to in our study. From the study results, most respondents landed on misread signs and taking the wrong exit from a roundabout, getting into the wrong lane was the second, and disregarding speed limits late at night was the third. Their study results are similar to our study results as the reported top-rated behaviours agree with our results although their rated scores are somewhat different. This case study also confirmed that vision impairment is a main cause of changing elderly driving behaviours.

Interestingly, the behaviour of changing focus to, for example, switch on a device has unexpected results from the survey. We thought that switching on a functional button in the vehicle system could not be difficult for the elderly drivers. However, they said that many functional buttons in the vehicle system are distracting and they become embarrassed when they are faced with an emergent situation on the road. And, small icons and text on the button can cause errors in their behaviour.

From our study, we could be led to believe that current system design and development have not considered special conditions for the elderly yet. Moreover, all of the elderly respondents disagree that current vehicle systems do not consider elderly group's health conditions and do make them drive with confidence on the road. Therefore, it is clear that further system designing and developing for elderly drivers should focus on the target users' functionality.

5 New Solutions: Addressing challenges for the elderly drivers

Based on the survey results and current studies for the elderly, we have found that current developments are not yet sufficiently beneficial due to some drawbacks and there is a need for improvement for safer driving environments for elderly people. With the exploration of the problems in the current systems, we can propose better assistive systems for elderly drivers to address their challenges. To effectively support the elderly's driving, diverse aspects of these challenges should be addressed. Since the elderly group has some health issues, currently applied technology and design should be differentiated, the needs of the target users should be more carefully considered in the system, and many companies and organizations should consider how to make and promote such an assistive system that can be beneficial for the elderly group. According to Fairchild et al. (2009), for feedback to be effective, advice given to the driver must be timely and useful, enabling the driver to take action that will improve driving performance in one or more ways. To do so, we suggest integrated solutions that should be addressed from different views of utility.

5.1 Technology Driven Solution

A lot of systems for elderly drivers have been utilized by different high technologies. However, the fact that   road traffic accidents among the elderly are still high prove that we should explore different technologies that the elderly users can use more practically with their declining health conditions. When designing biomechanical or physiological parameters, it is important to integrate sensors that are easy to use, comfortable to wear, and minimally obtrusive. Here we suggest utilising sensing technologies for the elderly drivers because sensory impairments are the most common symptoms with aging. Two sensing technologies that can be suitable for the elderly drivers are introduced.

1)   Using Wearable Sensors:
Wearable sensors have been widely used in medical sciences, sports and security. Wearable sensors can detect abnormal and unforeseen situations, and monitor physiological parameters and symptoms through these trackers. These days, this technology has transformed healthcare by allowing continuous monitoring of patients without hospitalization. Medical monitoring of patients' body temperature, heart rate, brain activity, muscle motion and other critical data can be delivered through these trackers. With this trend, this wearable sensor can be practically used for the elderly's safe driving. Under the current systems developed, elderly drivers have been passive when using in-vehicle systems by simply following directions of the system. For example, when a system warns a dangerous situation with signals, the users just react according to the system guidelines. So, there is a gap between the warning signal and its reaction. However, allowing physical access to a device can make the users more active and manageable. In particular, the wearable sensors could manage the health conditions of advancing age. When the elderly person is in a bad condition, the sensors can detect such a condition and inform the vehicle system. Then, the vehicle system can deliver the information to the elderly person and make them avoid driving or advise them to drive carefully on the road. Moreover, elderly drivers who have vision impairments can easily recognize an emergent situation on the road by directly receiving the warning signals to the wearable device attached to them.

2)   Emotional state monitoring inside vehicle:
A facial recognition sensor is capable of identifying or verifying a person from a digital image or a video frame from a video source. One of the ways to do this is by comparing selected facial features from the image with a facial database. This sensor can be also utilized to the system for safe driving in the elderly population. When a person feels bad or is sick, this can be evident in facial expressions. If the sensor captures the emotion of the users and informs a vehicle system, the vehicle system can help reduce driver's workload. In fact, the most relevant technological considerations revolve around enhancing user satisfaction and adoption. With both wearable and facial expression recognition sensors, MIT Lab developed a system using physiological signals to help a driver better cope with stress (Healey and Picard, 2005). Physiological signals are a useful metric for providing feedback about a driver's state because they can be collected continuously and without interfering with the

driver's task performance (2005). Continuous monitoring, with the sensor constantly assessing the driver's state assessment, is fast enough to initiate customized changes to the driver's in-vehicle environment to help mitigate emotional distress (2005). In high stress situations, some users might prefer visual navigation prompts to turn off or dim, since these types of warnings have been found to have a negative impact on situational awareness (2005). Also, by using an aggregate of continuous records of driver stress over a common commuting path, city planners could help quantify the emotional toll of traffic "trouble spots" which could help prioritize road improvements (2005).

Based on the original ideas for sensor development, this can make the system to be more useful for the elderly drivers since health conditions affected driving performance more than other age groups. This information could then be used automatically by adaptive vehicle systems in various ways to help the driver better manage their conditions. During high stress situations, cell phone calls could be diverted to voice mail and navigation systems can be programmed to present the driver with only the most critical information to help reduce driver workload. In addition, when the elderly drivers feel angry, the music selection agent in-vehicle system could lower the volume, offer a greater selection of relaxing tunes, and provide the driver with more entertainment options to help cope with their feelings of anger.

5.2 User Need-Based Solution

Defining user needs is the first and most critical component of the design process. It has been shown that inclusion of user needs in the design of assistive devices results in improved safety, improved usability, reduction in device recalls, limited need for modifications, improved user satisfaction and assists with obtaining development grants. When user needs and user abilities are not properly understood by the development team, resources will be wasted in creating systems that the target user neither needs nor wants.

In the automotive industry, older people have become a royal customer since the aging population has been growing all over the world. Also, people who are over 50 years old who purchased higher-end premium vehicles have the majority of new in-vehicle systems (Guo et al., 2010). However, while these older consumers are the first buyers of these new technologies, they may be the least likely to rapidly learn and use these systems and have been excluded from such a new technological development.

In a study on identifying user needs and requirements for the development of new technological solutions in elderly care, Prazak et al. (2007) found that the most important user needs for elderly users are safety and security, with social contact and communication issues also stressed. Although these user needs are related with their health conditions, new devices, interfaces, warnings, navigation, entertainment and related systems are introduced targeting general customers. Thus, user needs should be captured through various processes, each having their own advantages and disadvantages, such as diverse case studies, contextual inquiry, focus groups, and usability tests.

Based on the literature reviews, surveys, and interviews conducted from this study, the elderly needs are defined as below.

1) Applying the elderly's aging body conditions to a system:
Many studies revealed that one of the reasons why current vehicle systems with high technologies are not beneficial enough the elderly drivers from was because current systems do not consider the elderly's declining health conditions in the system design and development. In other words, technologies are used to mitigate the risks posed to the general driving population rather than reduce crashes or injuries for older drivers. Therefore, surveys, interviews, and focus group tests and observations should be conducted to understand their needs and why there are difficulties in their driving. The categories of the user need would vary by different regions, gender, ages, and health conditions.

2) Affordable to pay:

13

There are many systems utilized by high technologies; however, most drivers are not benefiting from the system due to their limited budget. Since most elderly drivers are about to retire or have already retired from their work, they want to save their money for the remainder of their lives. Therefore, if the system for the elderly is high-priced, they can't afford to buy the system. If systems are not dominantly beneficial to the majority of elderly drivers, the systems would not be considered as useful and would disappear from the market sooner. Therefore, it is key to develop a system with competitive prices that every elderly person could take advantage of — one that would improve their safety and take their aging body conditions into consideration.

3) Easy to operate:
Not all challenges that an elderly user may face are the result of a physical, age-related impairment. The differences between generations can also pose unique challenges for the elderly user. Elderly users often find that they have less experience with modern technology than others. Lack of experience with particular system interfaces can make them more difficult to operate. Even elderly users with some technological experience in the vehicle systems said that the current pace at which technology is moving is so rapid that users often can find themselves having trouble keeping up with modern technological trends. Therefore, an audio-based quick introductory tutorial in the vehicle application can be a useful for them to learn and enough usability tests with elderly customers and bringing their opinions to the development process should be conducted.

5.3 Market Driven Solution

A lot of automotive companies have paid attention to the elderly market as the number of licensed drivers over the age of 65 has been growing with the increasing aging population. Today, that common language is at risk and efforts to identify the ideal strategy to integrate new technologies safely into the elderly driver's vehicle is both a business and safety imperative. Successful deployment of active safety strategies, where the car takes a more 'active' role in anticipating and averting an accident, may meet their greatest challenge from the capacity of older drivers to learn, use, value and trust these new systems.

However, the industry has been remarkably successful for decades in introducing innovation, though new safety features have not satisfied elderly customers yet. To establish a strong market for elderly users, both the target user's needs and proper technologies should be carried out. If developers do not interact with their target customer base, they just pour money and effort into developing features that the elderly would not use in the end. This is not just about making a particular system for the elderly. When developers make a vehicle system, they should make it more user friendly for the predominantly elderly customers. Also, since no policy exists for developing for elderly drivers, particular policies for their target market should be developed. If there is a particular policy and concrete guidelines for developing a vehicle system for elderly drivers, this can help accelerate workflow and make development of accessible systems an easier process and on that is more marketable for the industry.

6 Conclusion and Future Research Directions

This research provided different perspectives with which to anticipate safe and usable solutions of elderly drivers in hopes of mitigating accidents. It described the elderly's fatal accident rates in different regions, analysed the drawbacks of systems from current studies, and highlighted the significance of system design. Additionally, we addressed diverse aspects of challenges as a feasible solution through interviews and survey with 60 elderly people, and as a result, we gained insight into what type of safe-driving systems would be most beneficial to them.

The research aim is to make the elderly drivers easily accessible to smart vehicle systems and improve their driving conditions via the systems in the vehicle. Some might think that the suggested solutions are not unique but visionary. However, we have experienced that how current system could not help the elderly's safe driving although they used many advanced high technologies. In this point,

we would like to emphasize as a conclusion that integral solutions can be the best if they applied to what users want and need to have. Also, suggested solutions would be more feasible that the elderly users can be satisfied because we approached the system development that can be created easier than other advanced systems in the aspect of usability, cost, and technological productivity. Therefore, customisable safety systems for elderly drivers with age-related health conditions will be an essential concern to mitigate the elderly's accidents and have them enjoyable driving experiences.

This research work is limited by a number of factors. First, few people participated in the focus groups, aged 55 to 75 years, and they represented only a few countries, i.e., Japan, U.S. and U.K. Bias might occur when applying the established systems to elderly in other regions and to larger numbers of elderly drivers. Due to the safety systems involved with diverse aspects such as HCI, cognitive ergonomics, information systems, human factors, social sciences, and so forth, further research for the system development will consider more elderly drivers in different regions (Sharp et al., 2007).

Second, a limitation of our research is that we have only suggested some diverse and integral solutions for the elderly's safe driving and usable system development. Thus, since suggested solutions are not tested yet with an actual design system. The suggested solutions could be changed from actual tests with more diverse ideas. In future work, we would develop the concepts based on the suggested solutions and test how the concepts work well for the elderly group and the concepts will be refined based on the test result.

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