Design Considerationsfor the Older Population

A Human-Vehicle Interface Perspective

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Abstract—**Recent technological advances have enabled a widevariety of information systems to be integrated into avehicle in order to increase safety, productivity, andcomfort.However, improperly deployed technology can increase driver's workload and, consequently, degrade safety.Especially, potential information overload problems may become acute among older drivers who are the fastest growing segment of the driving population.Thusautomotive interface designers must carefully balance the desire to introduce novel systems with the limited attentional capacity of the older drivers. In this paper, the older drivers' limitations such as hearing loss and cognition, and the challenges in automotive interface design for the older drivers were discussed. Based on the older drivers' limitations, automotive interface design considerations for the older drivers weresuggested.**

Keywords-Global Aging Society; Older Driver; Age-Induced Limitation; Automotive Interface Design; Driving Workload

I. Introduction

Society is "getting older"and this aging of society is occurring worldwide as can be seen in Figure 1. Improvements in health are leading global demographic changes during the past century. For the world as a whole, lifeexpectancy more than doubled from around 30 years in 1900 to 65 years by 2000 and isprojected to rise to 81 by the end of this century[1].Population aging will be most rapid in Western Europe, the United States, Japan, and Korea.The number of people 65 years old or older expected to double in the United States and triple in South Korea between2000 and 2030.In Japan 42% of the population is projected to be aged 60 or over by2050, with 16% aged 80 or over. Japan has recently become the first country in history with anaverage age of over 40. Japan is projected to have nearly one million centenarians by 2050 [2].

Korea also rapidly enters into the aging society. The United Nations definesan "aging society"as a country where 7 percent or more of the population is aged 65 years or older, "aged society" as 14 percent or more, and "super-aged society" as over 20 percent. Korea already passed an aging society, and this demographic change is currently following the global trend [3]. As aging is being spread, Korea faces with the considerable issue among other economic and cultural issues; How to make up the living condition to fulfill requirements of the older population. We are at the point of the time to ask ourselves, whether the design of living facilities, social infrastructure and devices are conceptualized in the way that the physical, emotional and congenial characters of the older adults are reflected. The learning mechanism and the way of the information interpretation is not the same as the young adults. In addition, declined physical ability caused by aging spurs the necessity for another approach for controlling products. The question of the elderly friendly design is also relevant tonew in-vehicle technology and the driving environment.With increasing rate of the elderly standing at well educated and high income level, in the market, they are not just limited as simple user but wield as consumer with significant purchasing power. The demands of the older consumers in the automobile industry will be important factor to decide the direction of technology development and diffusion. To accommodate the new older driver, for example, the caris becoming more user-friendly. It is now easierto get into and out of several models.Well-placedhandles help sore knees mount a high SUV.Larger mirrors and windows now accommodatevisibility for stiffer necks toassess blind spots, while innovativeglass coatings and dashdesign have reduced glare forolder eyes. These kinds of elderly friendly designs are developed from the knowledge of physical and visual degradation of the older adults.

However, the older drivers' degradation in cognitive capacity was not carefully considered yet, because the knowledge of cognitive capacity changes with aging was limited. In this paper, the older drivers' limitations such as hearing loss and cognition, and the challenges in automotive interface design for the older drivers were discussed. Design considerations in human-vehicle interface for the older drivers were suggested.

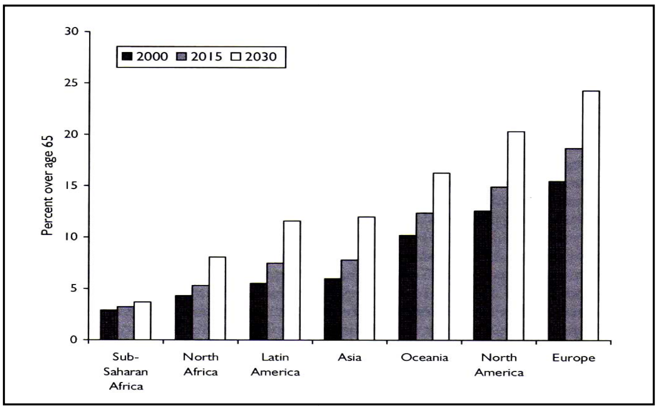

Figure 1. Percentage of the population older than age 65, currently and estimated for the future (Source: Kinsella and Velkoff, 2001)

This research was supported by Daegu Gyeongbuk Instituteof Science and Technology (DGIST) Research Program of theMinistry of Education, Science and Technology (MEST).

II. AGE-INDUCED DEGRADATIONS AND SAFETY

Age brings with it many capabilities, such as increased wisdom, experience, and knowledge. However limitations which are associated with perception, cognition, and the control of movements increase in prevalence as one ages. The limitations of audition and cognition will be focused in this paper.

A. Audition

Various estimates suggest approximately 10 percent of all middle-aged adults suffer hearing losses of a magnitude that hinders social interaction. By age 65 or so, the percentage has jumped to more than 50 percent of all men and 30 percent of all women.Normally, young adults can hear pure tones in frequencies up to 15,000Hz. Beginning around age 25, presbycusis– an age-related loss of the ganglion cells necessary for conduction – causes erosion of the upper threshold, and after age 65 or 70, sound above 4,000Hz may be inaudible [4].

Figure 2 shows the pure tone audiogram result of age groups. Thisexperiment was conducted by the Daegu Gyeongbuk Institute of Science and Technology (DGIST) at Fatima Hospital to assess age-related hearing loss. The decrement of older participants'hearing ability is clearly observed at sound above 2,000Hz[5].

Figure 3 shows the physical response of drivers by age for differentwarning-sound intensities. The upper part of the bar (oblique lines) representsthe accelerator response time while

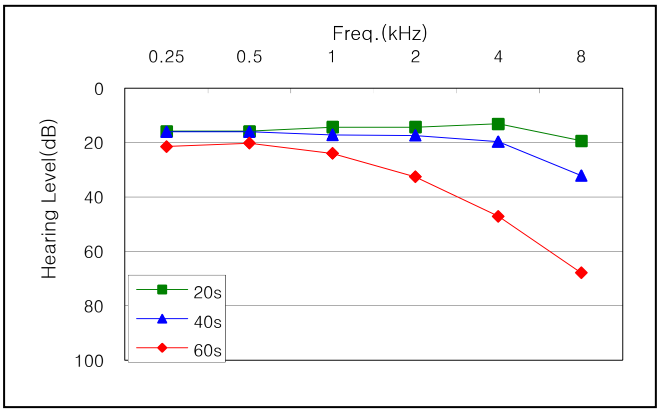

Figure 2. Pure tone audiogram result of age groups

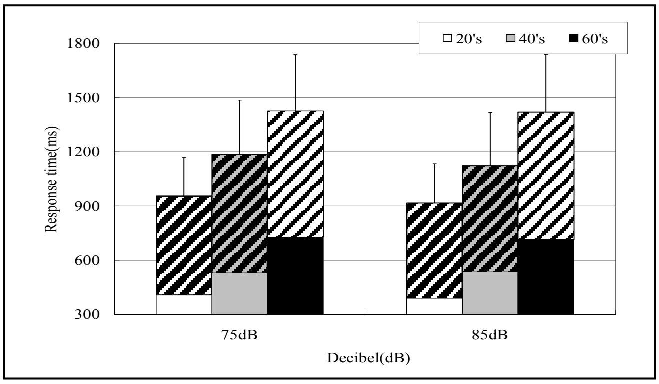

Figure 3. Response time for different intensities according to age group.

the lower part is the brakeresponse time. Drivers in their twenties and forties had shorter acceleratorresponse times as the warning sounds became louder, whereasolder drivers showed no significant difference. In other words, olderdrivers are less sensitive to changes in warning sound intensity. Theaverage accelerator response time of older drivers was 170 ms longerthan that of drivers in their twenties and 86 ms longer than thatof drivers in their forties.

B. Cognition

Cognition refers to a faculty for the processing of information, applying knowledge, and changing preferences.Within psychology or philosophy, the concept of cognition is closely related to abstract concepts such as mind and intelligence. Thus cognition is used to refer to the mental functions or mental processes.

The cognitive capabilities related to memory (working memory and long-term memory), visual attention, spatial cognition, multiple task demands and so on. In those constructs, multiple task performance of older adults will be mainly discussed in this paper, because it is common for adriver operating a motor vehicle to engage in many non-drivingtasks, such as talking and texting on a cell phoneand operating navigational aids and entertainment systems.When younger and older adults are required to perform more than one task at a time (such as driving and looking for street signs) it is generally true that older adults performed more poorly doing two tasks at once as compared to their younger counterparts. Older adults do not perform as well as young adults in dual-task conditions, and the magnitude of the age difference increases with the magnitude of task difficulty [4].

Table 1compares the average error rates of auditory delayed digit recall task between younger and older adults under single and dual task conditions. In this study, the auditory delayed recall task, an n-back task, was administered as a series of 30 second trials consisting of pre-recorded aural presentation of a series of single-digit numbers at an inter-stimulus interval of 2.7 seconds (See details in [8]). With each digit presentation, the participants' task was to say out loud the "nth" stimulus back in the sequence. The task was given as a set of six trials, employing low demand in the first two trials (0-back), moderate demand in the second two trials (1-back) and high demand in the final two trials (2-back) [5-8].The participants carried out the n-back tasks under non-driving, and simulated urban and highway driving.

TABLE I. ERROR RATES OF DELAYED DIGIT RECALL TASK

Age	**Non-Driving**	**Dual task**	
		Urban	***Highway***
20s	4.43 (6.77)	9.22 (9.42)	7.60 (9.98)
60s	29.81 (24.56)	42.13 (21.51)	33.67 (22.22)

*mean (standard deviation)

In the urban section, the n-back results showed significant differences between when the subjects were driving and when they were not driving (F(1,114)=7.390, P=0.008). The error rates when driving increased by 4.79% among subjects in their 20s and 12.32% among subjects in their 60s compared to when they were not driving.In the highway section, however, the n-back results did not show a significant difference between when the subjects were driving and when they were not driving (F(1,114)= 1.283, P=0.260). This result seems to be related to the different level of cognitive workloads were required in different traffic environments and the compensatory behaviors of lowering speed. In other words, the drivers seemed to minimize cognitive workload from driving and tried to focus on the n-back task by reducing speed sufficiently in the highway section, which has a lower driving workload than the urban section. As a result, they maintained a similar cognitive ability to the non-driving condition, and the difference in error rates between the existence and no existence of dual task was not high. For the 60s group, the average speed during the n-back task decreased by 9.5% in the highway section, whereas it decreased by 7.0% in the urban section. The result demonstrated that older adults perform as well as young adults where tasks are relatively simple like slower driving on the highway.

C. Older Driver Safety

At the previous sections, we reviewed older drivers' limitations,which can affect driving safety, such as a decreased hearing ability at high-frequency sound, longer pedal response time, and poor multiple task performance. Despite older drivers' diminished capacity, driving judgment increases with experience and age which may compensate for decreased capacity [9]. Thus,normally, older drivers manage very well, but in situations producing veryhigh momentary mental workload, they sometimes fail with severeconsequences [10-11].As shown in the National Highway Traffic Safety Administration's (NHTSA) Fatality Analysis Reporting System (FARS) driver fatality data (Figure 4), older drivers are more likely than average drivers to be seriously injured or killed while driving. As drivers age, theybecome more susceptible to distraction, attentional capacity decreases, and the ability to quickly shift attention between multiple stimuli is lost. As a result, older adults may be placed at greater risk from interactions with complex or confusing information systems.

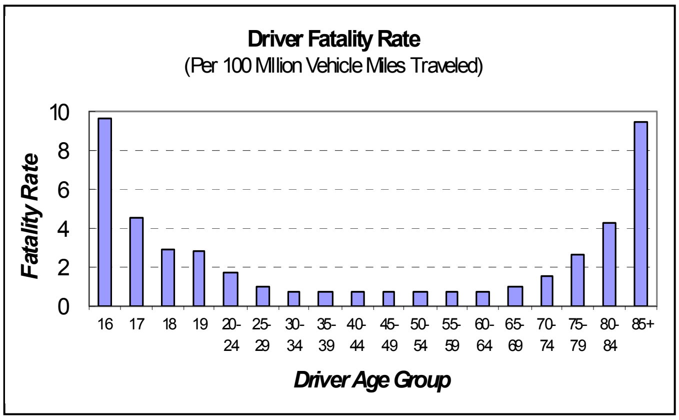

Figure 4. The US Driver Fatality Rate by Age

Similar statistics were found in Korea as well. According to a study by the Korean Road Traffic Authority, the number of traffic accidents among older drivers aged 61 or older is steadily increasing, and about 69.1% of traffic accidents are caused by inattentive driving, such as failing to look forward, judgmental error, and delayed discovery. Typical causes of this inattentive driving are the operations of convenience and information systems, such as mobile phone and navigation systems [12-13].

III. Challenges in Automotive Interface Design

Safety and ease ofuse are important determinants in the design of human-vehicle interfaces. But older and younger drivers have different characteristics in design acceptance and learning behavior. These differences make challenges in automotive interface design.

A. Innovation Paradox

Over the next ten years, at least 25% of automobile buyers will be over age 50. These "older" consumers purchase the premium luxury vehicles that deliver the majority of new in-vehicle systems and the industry's highest profits margins. Thus, older consumers present an innovation paradox, that is older driver should be a lead adopter of new technology, to the automobile industry. Automotive market experience has examples of where new technology has challenged the older consumer. For example, BMW courageously introduced a new metaphor in driving – the iDrive. However, the initial introduction of the iDrive system met with criticism from customers and industry analysts. Over time, modifications have been made to the iDrive to make it more user-friendly for the predominantly age of 45 or over.

B. Different Learning Behavior

Younger and older drivers learn to use new systems differently. For example, older drivers have been shown to be distracted from the driving task when the cause of a warning was not clearly evident. In contrast, younger operators, by definition with fewer years of driving experience, were shown to have more trust in warning systems often choosing to rely on the system.Successful deployment of active safety strategies may meet their greatest challenge from the capacity of older drivers to learn, use, value and trust new systems. Features such as brake assist, audible and haptic collision warning systems, fatigue and lane deviation detection, visual warning display on the dash and eventual Heads-Up-Display (HUD) systems will require the older experienced driver to learn how to drive in a new way.

C. Driver workload and in-vehicle tasks

The ability to manage driving workload is an essential aspect of safe driving, because driving workload can degrade driving performance. The possibility of accidents will increase whenthe driver's performance is lower than the driving environmental requirements.

According to the final report of Driver Workload Metric Project [14], driver workload is defined as the competition indriver resources (perceptual, cognitive, physical) between the driving task and aconcurrent subsidiary task, occurring over the task's duration, as manifested indegraded lanekeeping, longitudinal control, object-and-event detection, or eyeglancebehavior.

Another studies show that operating or talking ona mobile phone while driving results in increased workload and greaterlevels of frustration, particularly when the conversation is complex or highly emotional[15] and operating a route guidance system whiledriving also increases workload [16]. Figure 5 presents typical in-vehicle tasks that have been classified by the input and output modalities needed to perform the task [14]. As shown in the classification, driver workload can be assigned into two categories, i.e. visual and cognitive, although there are more complex tasks which require both visual and cognitive demand.

IV. Design Considerations for Older Drivers

As mentioned before, the fact that improperly implemented interface design can increase driver distraction and hasbecome a major concern in the automotive safety field. Therefore, automotive interface designers must carefully balance the desire to introduce novel systems with the limited attentional capacity of the driver. In this section, automotive interface design considerations for the older drivers will be discussed.

A. Audible Interface Design

The previous study found differences in accelerator response time(160 ms) and brake response time (320 ms) between young drivers andolder drivers due to age-related hearing loss, cognitive process and declining muscularstrength. This fact should be considered when designing audible interface for older drivers. The study recommended the audible warning sound in terms of tempo and frequency for older drivers as shown in figure 6. Thus, Designers of products and environments must be cognizant of changes in hearing capability influencing older adults' ability to detect tones and other sounds and of changes in ability to comprehend speech.

B. Visual Interface Design: Cognitive Perspective

Dynamic visual attention is another aspect of cognition that can be related to successful interaction with products orenvironments.Dynamic visual attention is how we scantheenvironment and involves focusing attention in one location and then another location. However, the ability of a person to focus attention and then reorient that focus is limited by the availability of a finite amount of attention-related resources. It can take almost a second to reorient attention from one item of interest to another, even under ideal, controlled laboratory situations. Generally speaking, older adults require more time to orient attention from one location to another.Attention is captured by highly salient events in the environment, and other stimuli will not be processed during this capture of attention. Older adults tend to be more affected by salient events [4].

In designing for older adults, it is critical to require the smallest possible number of things to search through to perform a task. It is also to remove extraneous information that might "capture" attention (such as blinking display elements on a GPS).

C. Multiple Tasks Design : Cognitive Perspective

Previous research results generally demonstrate a slowing of response as a function of age. When younger and older adults are required to perform more than one task at a time (such as driving and looking for street signs) it is generally true that older adults performed more poorly doing two tasks at once as compared to their younger counterparts. Older adults do not perform as well as young adults in dual-task conditions, and the magnitude of the age difference increases with the magnitude of task difficulty. However, in some situations, where tasks are relatively simple, older adults perform as well as young adults.

When a design that is introduced requires older adults to perform novel activities, it is critical not to require the combined performance of tasks or components of tasks.

V. Summary

Driving is a complex psychomotor task often interrupted bysecondary activities that divert attention away from the roadway. Diversion of attention to secondary tasks is one of the largest contributors to inattentive driving and, consequently, to accidents. Therefore, when designing automotive interface, the limitation of visual and cognitive resources, due to the primary task of driving, should be considered.

As drivers age, their audition and cognition weredegraded. As the result, older adults may be placed at greater risk from interactions with complex or confusing information systems. The US and Korean statistics of driver fatality rate by age

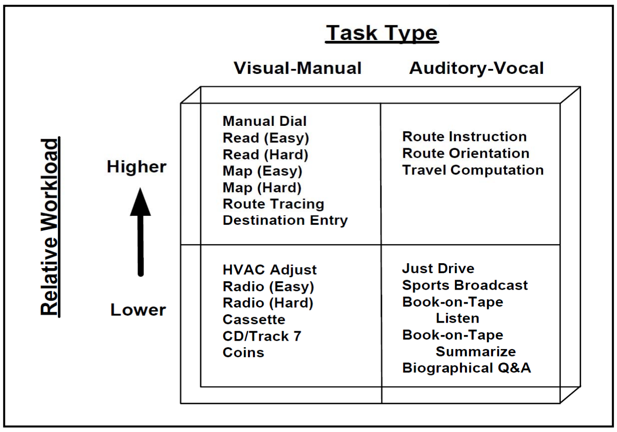

Figure 5. Typical in-vehicle tasks classification

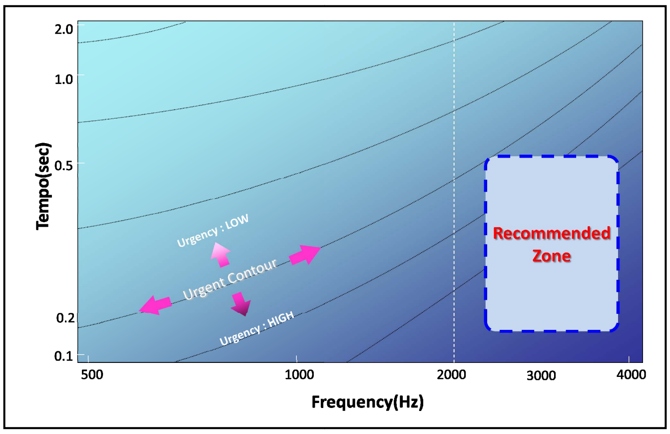

Figure 6. Recommended audible warning sound zone for older

demonstratedthe severity of older driver's safety. A few previous research results were presented to provide evidences about behavioral differences between older and younger drivers.

In order to overcome the audible and cognitive degradation of the older drivers, the automotive interface design considerations were suggested in terms of the audible and visual interface, and multiple task demands.

ACKNOWLEDGMENT

The authors would like to thankYunsuk Park, Suwan Park, Taeyoung Lee and Myoung-ouk Park for their assistance with data collection and thepresentation of this research.

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