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# Toward best practice in Human Machine Interface design for older drivers: A review of current design guidelines

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ABSTRACT

Older adults are the fastest growing segment of the driving population. While there is a strong emphasis for older people to maintain their mobility, the safety of older drivers is a serious community concern. Frailty and declines in a range of age-related sensory, cognitive, and physical impairments can place older drivers at an increased risk of crash-related injuries and death. A number of studies have indicated that in-vehicle technologies such as Advanced Driver Assistance Systems (ADAS) and In-Vehicle Information Systems (IVIS) may provide assistance to older drivers. However, these technologies will only benefit older drivers if their design is congruent with the complex needs and diverse abilities of this driving cohort. The design of ADAS and IVIS is largely informed by automotive Human Machine Interface (HMI) guidelines. However, it is unclear to what extent the declining sensory, cognitive and physical capabilities of older drivers are addressed in the current guidelines. This paper provides a review of key current design guidelines for IVIS and ADAS with respect to the extent they address age-related changes in functional capacities. The review revealed that most of the HMI guidelines do not address design issues related to older driver impairments. In fact, in many guidelines driver age and sensory cognitive and physical impairments are not mentioned at all and where reference is made, it is typically very broad. Prescriptive advice on how to actually design a system so that it addresses the needs and limitations of older drivers is not provided. In order for older drivers to reap the full benefits that in-vehicle technology can afford, it is critical that further work establish how older driver limitations and capabilities can be supported by the system design process, including their inclusion into HMI design guidelines.



## 1. Introduction

Over the next five decades, there will be a substantial increase in both the number and proportion of older people in most industrialised countries as a result of the baby boomers' maturation, lower birth rates and increased longevity (OECD, 2001). With the aging of the population, it is also anticipated that there will be an increase in older drivers' licensing rates (Koppel and Berecki-Gisolf, 2015; Sivak and Schoettle, 2011). Further, the private motor vehicle is likely to remain the principal mode of transport for the emerging cohorts of older drivers who will be more mobile, travel more frequently and travel greater distances compared with earlier cohorts (OECD, 2001). Demographic growth, increased licensing rates, and increased motor vehicle use will combine to produce a marked increase in the number of older drivers on the road (Koppel and Berecki-Gisolf, 2015; Koppel and Charlton, 2013).

While there is strong conceptual support around the world for older people to maintain independent vehicular mobility for as long as possible, their safety is also a serious community concern necessitating development of innovative measures to reduce crash and injury risk (Langford and Koppel, 2006). While current figures show that older drivers are involved in few crashes in terms of absolute numbers, they represent one of the highest risk groups for crashes involving serious injury and death per number of drivers and per distance travelled (Koppel et al., 2011; Langford and Koppel, 2006).

For the most part, older drivers' elevated risk for serious injury and fatal crashes can be explained by their frailty or reduced biomechanical tolerance to crash forces (Li et al., 2003). The energy required to cause injury reduces as a person ages (Augenstein, 2001): older adults' biomechanical tolerances to injury are lower than those of younger persons (Mackay, 1988; Viano et al., 1990), primarily due to reductions in bone and muscular strength and fracture tolerance (Dejeammes and Ramet, 1996; Padmanaban, 2001). Li et al. (2003) used the US Fatality Analysis Reporting System (FARS) and a national probability sample of all crashes (both non-casualty and casualty) to compute the role of frailty in older driver crashes. After statistical correction, the authors reported that older

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drivers' (and especially older female drivers') over representation in fatalities could be explained mainly by frailty, accounting for around 60–90 percent of the fatalities.

In addition, for some older drivers, declines in a range of age-related sensory, cognitive, and physical impairments can also place them at an increased risk of crash-related injuries and/or death, including: a decline in visual acuity and/or contrast sensitivity; visual field loss; reduced dark adaptation and glare recovery; loss of auditory capacity; reduced perceptual performance; reductions in motion perception; a decline in attentional and/or cognitive processing ability; reduced memory functions; musculoskeletal declines and strength loss; postural control and gait changes, and slowed reaction time (Janke, 1994; Stelmach and Nahom, 1992).

If used appropriately, In-Vehicle Information Systems (IVIS) and Advanced Driver Assistance Systems (ADAS) have the potential to assist all drivers with the complex demands associated with the driving task (Vrkljan and Miller-Polgar, 2005). For older drivers in particular, these systems have the potential to assist them to reduce exposure to hazardous driving situations by compensating for age-related sensory, cognitive and physical declines (Caird, 2004; Davidse et al., 2009), while also maintaining mobility (Koppel and Charlton, 2013; Koppel et al., 2009).

For example, Ling Suen and Mitchell (1998) listed the known functional impairments and associated driving problems that drivers tend to develop as they age and identified possible in-vehicle technology or equipment to address these problems (see Table 1 for an updated version of Ling Suen and Mitchell's table).

However, these technologies only have the potential to benefit older drivers if their design is congruent with the complex needs and diverse abilities of this driving cohort (Vrkljan and Miller-Polgar, 2005). For example, as noted by Meyer (2004), lowered acuity and contrast sensitivity are common among older drivers, therefore displays should be at a brightness level that differs as much as possible from the background. Dobres et al. (2016) also found that certain typefaces, colours and styles are less legible across the lifespan and that older people are more strongly affected by suboptimal interface text designs. In addition, intelligent on-board "workload manager" technologies have the potential to determine if a driver is overloaded or distracted, and if so, alter the availability of telematics and the operation. For example, the system may temporarily suppress calls and prevent access to phone functions and controls when distraction potential is estimated to be high (Regan et al., 2001). Several authors (Brennan et al., 1997; Regan et al., 2001; Vrkljan and Miller-Polgar, 2005) have proposed that if the underlying principles of universal design and human factors are integrated from the beginning of the design process for devices, such as IVIS, it may increase the likelihood that drivers of varying abilities, including older drivers, will be able to use the product (Koppel and Charlton, 2013; Koppel et al., 2009).

The design of ADAS and IVIS is largely informed by automotive Human Machine Interface (HMI) design and performance guidelines, of which a number currently exist (e.g., European Statement of Principles (ESoP); Alliance of Automotive Manufacturers (AAM) Statement of Principles, etc). Automotive guidelines are designed to inform the safe design and assessment of in-vehicle systems, particularly in relation to driver workload and distraction. Design guidelines are practices that are desirable to follow, but are not mandatory; as such, they are typically less stringent than standards (Green, 2009). They vary in terms of their level of detail, with principles ranging from broad (e.g., "be consistent") to highly specific (e.g., specific colours to be used). More detailed guidelines precisely state how a product should be designed; however, because of their level of specificity, may be useful for only a small range of technologies. In contrast, broad higher-level guidelines are typically user-centred and 'technologically neutral' meaning they can apply to multiple systems (Stevens, 2009) and remain relevant when technology is changed, advanced or updated. However, they can be written in such a general way that they are open to interpretation and difficult to apply to a given context. The scope of many guidelines are also restricted in terms of the users they target, with many aimed at private (i.e., non-commercial) passenger vehicle drivers and most do not include additional requirements or accommodations for drivers with special needs, disabilities or other impairments.

This paper was stimulated by questions relating to the extent to which potential age-related sensory, cognitive and physical declines of older drivers are addressed in current automotive HMI guidelines. The need for the design of in-vehicle technologies to consider the functional capacities, needs and limitations of older drivers is paramount, as this population is likely to be one of the first to encounter the technology given that systems are typically introduced into the higher-end vehicles often bought by older drivers (Eby and Molnar, 2012; Koppel and Charlton, 2013; Meyer, 2014). This paper provides a review of current guidelines for IVIS and ADAS with respect to how, and to what extent, they address age-related changes in sensory, cognitive and physical abilities. A key focus of the review was on the design guidelines pertaining to visual displays and input controls.

## 2. Material and methods

### 2.1. Systematic review of design guidelines

A comprehensive review of the English-language automotive HMI design guidelines was performed covering selected documents published in the period from 2000 to 2015. Design information relating to older persons and the impact of aging on sensory, cognitive and physical functions for use of in-vehicle technologies such as ADAS and IVIS was the focus of the search.

Guidelines selected for inclusion in the review were: European Statement of Principles (ESoP) (European Commission, 2008); Alliance of Automotive Manufacturers (Alliance of Automobile Manufacturers, 2006) Statement of Principles; Japanese Automobile Manufacturers Association Guidelines (JAMA, 2004); Transport Research Laboratory (TRL) Design Guidelines (Stevens et al., 2002); Battelle Crash Warning System (CWS) Interfaces guidelines (Campbell et al., 2007) and NHTSA (2012) Phase 1 Visual-Manual Driver Distraction Guidelines for In-Vehicle Electronic Devices. The guidelines reviewed represent the major automotive design guidelines published or updated since the year 2000.

The guidelines were searched for inclusion of the following key words: *old/older/elderly driver; age, seniors, impairment, sensory, cognitive and physical function and ability, universal design, inclusive design, user-centred design and interaction design.*

The keyword searches revealed limited hits within the selected guidelines, therefore the search was expand to also include two SAE Technical Standards that specifically relate to automotive technology design for older drivers – SAE J2119 (1997) and J2217 (1991). The above keywords were also applied to these technical standards.

### 2.2. Data abstraction and analysis

Following key word identification, guidelines were appraised by one reviewer in more detail to identify the extent and context in which specific guidelines address the cognitive and physical impairments experienced by older drivers. Included in this appraisal was a count of the outcomes of interest (frequency of key word use), and relevant descriptive content pertaining to each keyword usage.

A second reviewer appraised each set of guidelines independently. When discrepancies arose, these were discussed and the

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