Older Drivers and New In-Vehicle Technologies: Adaptation and Long-Term Effects

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Abstract. The introduction of new technologies into vehicles has been imposing new forms of interaction, being a challenge to drivers but also to HMI research. The multiplicity of on-board systems in the market has been changing the driving task, being the consequences of such interaction a concern especially to older drivers. Several studies have been conducted to report the natural functional declines of older drivers and the way they cope with additional sources of information and additional tasks in specific moments. However, the evolution of these equipments, their frequent presence in the automotive market and also the increased acceptability and familiarization of older drivers with such technologies, compel researchers to consider other aspects of these interactions: from adaptation to the long term effects of using any in-vehicle technologies.

Keywords: In-Vehicle Technologies, Older Drivers, Behavioral Adaptation, Human-Machine Cooperation.

1 Background

One of the main reasons why road safety research has devoted considerable attention to older drivers is their growing representation in the population in most industrialized countries. In fact, the proportion of older drivers is increasing in society and is expected to enlarge even more [1] [2] [3]. The elderly population represents the most growing segment of the overall population. In most of OECD countries, it is expected that by the year 2030 one person out of four will be 65 years old and over [3]. This is explained by the maturation of the "baby boom" generation, combined with a greater longevity and the decline of birth rates. Furthermore, the number of older drivers is also increasing since the twentieth century 60s and much more young men or women got their driving license.

Driving has nowadays an important role in society and is essential to determine the quality of life of older people. Driving enables easy access to activities and services, to fulfill social needs and because of that it is a good indicator of mobility, independence, good health, quality of life and well-being. The car represents to the elderly the possibility of maintaining their autonomy and self-esteem being also a symbol and a way of freedom, independence and self-reliance [4] [5]. In contrast, the fact of not being able to drive is considered a limitation in life control, mobility and independence. Stopping driving seems to have consequences not only on elderly daily life but

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also a negative effect at a psychological level once it is reported to increase the feeling of isolation and loneliness [6] and depressive symptoms (as cited by Harper & Schatz in [5]). Besides the social and health disadvantages, older drivers report strong feelings about the importance of driving and extremely negative opinions about the loss of driving [7]. Ceasing driving means that their mobility is dependent of others or on public transportation. It is not surprising that many older drivers rely on their cars for most of their transportation needs, being strongly interested in keeping their own cars and licenses for as long as possible [3]. Additionally, they are sometimes reluctant to use public transportation because it doesn't fulfill all their travel needs; it is often considered as unreliable and perceived as providing inadequate personal security [5].

2 Older Drivers' Behavior and Safety Implications

Older drivers are generally considered safe and cautious drivers and it is frequently claimed that they self-regulate their driving behavior [4]. The age-related perceptual and cognitive difficulties of older people lead them to change their driving habits and often to give up driving, which affects their own mobility. Despite the age-related declines, older people can drive safely, compensating their failures by using their remaining abilities in a deeper way. In a healthy ageing process, age-related decrements don't have significant impact on task performance if previous experience can be used. Indeed, compensation based on the task knowledge and experience is the reason why some performance decrements in laboratory tests are not replicated in daily task performance. Anyway, older drivers avoid driving conditions that impose higher demands, such as driving at night, with poor weather conditions or during rush hours.

Despite an increasing individual diversity with ageing, it seems that, for the same task performance, older people develop the same compensatory behaviors for functional losses. This results in particular common patterns to compensate the age-related impaired perceptual-motor functioning. These characteristics, which act as compensation to their declines, can include the insight to one's own limitations, driving experience and some compensatory behavior [8]. Compensatory behaviors reduce the stress and anxiety felt by older drivers in some driving situations, as well as the risk of driving in these situations [9] [3]. As pre-conditions for the use of experience, a more stable and user-friendly road environment is required, which is not the case as the roadway system is more and more complex. Moreover, the driving-related interactions with new in-vehicle technologies increase the task complexity, reducing the possibility of using previous experience.

The great amount of driving experience that older drivers possess is also an important factor. The traffic experience acquired may give them the ability to anticipate some problematic situations and avoid the risk. Charlton and colleagues [4] present several examples of self-regulation behaviors: driving more slowly, travelling shorter distances, making fewer trips, avoiding driving under difficult conditions like driving at night or with a large amount of traffic, selecting for longer time gaps when turning or entering a road, and avoiding performing simultaneous activities while driving. Generally, older drivers tend to make trips shorter and closer to home (Rosenbloom as cited in [5]), avoid to drive in freeways, plan to use only routes where protected left turns can be made (for those who drive in the right hand-side of the road) and also drive with a co-pilot [10].

The major concern about older drivers' safety is not so much the potentially hazardous situations that they can cause but the risk that they are exposed to. In absolute numbers, the older drivers' crashes have been reported as lower than other age groups, especially the young drivers [11]. However, the overall number of older driver crashes may under-estimate the magnitude of the older driver problem as their total distance travelled tend to be lower when compared to younger drivers. This may have an influence on their crash rate because drivers that travel few kilometers have increased crash rates per kilometer compared to those driving more [4] [5]. In fact, when the distance travelled is taken into account, the fatality rate for the 75 years and older is more than five times higher when compared with the other drivers' group [8] [12]. This adjustment of crash rates for distance driven was reported by other studies and evidence that rates for the older drivers are not inferior to the ones observed for the younger group, giving rise to the concern of older driver population [13].

The causes of older road users' crashes are complex and there is no unique unequivocal explanation for them. Several explanations have been expressed by researchers to justify the over-representation of older drivers in fatal and serious injury crashes. Some argue that the older driver issue is mainly restricted to determined subgroups of older people, rather than related to all older drivers indiscriminately. They support that some clusters are more at risk and need to be identified in order to be done something about it [3]. One important difference between these at-risk populations is the survival rate of crashes once it is reported that seniors have lower surviving possibilities. After a motor vehicle accident, older drivers are four times as likely to be hospitalized, having also slower recoveries when compared with younger drivers (Dobbs as cited in [14]). This can also explain, at least partially, the elevated trauma of older road users. With increasing age, biological processes have the effect of reducing resilience to trauma and biomechanical tolerance to injury becomes lower. The reduction in bone and neuromuscular strength and also the diminution of the fracture tolerance make older drivers more fragile, susceptible to injury and with slower capacity to recover from trauma [4]. Seniors are more likely to have serious injuries or die from motor vehicle crashes because they are simply more medically delicate [15].

3 Older Drivers and ITS

Intelligent Transportation Systems (ITS) provide and use information about transportation conditions to improve system performance in such areas as safety, mobility, efficiency and environmental impacts [16]. ITS involve a wide variety of advanced and emerging technology applications designed with the aims of improving mobility, safety, travel efficiency, comfort and transit services, as well as reducing congestion, fuel consumption and emissions. In the context of driving, a distinction is made between two kinds of systems:

- Advanced driver assistance systems (ADAS) – devices that are designed to co-operate with the driver to achieve the trip goals, such as collision warning

systems, adaptive cruise control, lane departure warning, lane change aids, parking aids, etc.,
- In-vehicle information systems (IVIS) – in-board systems that provide the driver with information and allow communications from and to the driver; some of these systems are not related to the driving task, that is, they don't provide useful information for a safe driving, being a factor of distraction; telecommunications and infotainment systems (e.g., radio, mobile phone, e-mail, Internet access) are examples of IVIS competing with the driving task; other IVIS, like navigation systems, provide useful information but can be a factor of distraction as well if they don't support user's needs and are not compatible with human capabilities and limitations.

ITS represent a potential to increase safety and possibly save lives, as older drivers are particularly vulnerable. The benefits from the use of ITS by older drivers have been identified in several studies [17] [18]. As innovative technologies, intelligent transportation systems require adequate design in order to avoid the bad outcomes of well-intentioned but poorly designed technology. Even easy-to-use and somehow intuitive, ITS might require some training, helping the driver to make a safe use of the system or understand how to cope with the limits of the technology. When using ITS, drivers must understand the appropriate level of trust to place in the system as early research has shown that sometimes people place more trust in a system than it is designed to handle [19].

Due to a generation effect, elderly people are not used to advanced technology, which lead them to avoid and even reject new technological systems. It can be argued that in the near future, the elderly population will be more familiarized with new technologies; however, there will be always a gap between their experience with new technologies and the most recent technological advances. Furthermore, there are evidences that older people present some difficulties in terms of self-learning. Actually, learning performance and learning aptitude decline with age, particularly when the information presented increases in complexity or when the speed of that presentation is beyond the control of the subject. A new technology may create an additional complexity to older people due to the lack of occasion to use previous experience, which is the main resource of the elderly. According to Stokes [20], some handicaps of elderly people are more related to the associated effects of the ageing process and the under-stimulation resulting from their retired life than to the loss of intellectual capacity.

ITS technologies offer a range of benefits to transport systems and users: from safety improvements to capacity increases and operational efficiencies, environmental preservation and the provision of information. In the context of driving, ITS include vehicle control devices (Adaptive Cruise Control, rear-view cameras, backup proximity warnings, etc.); driving assistance devices (navigation, traffic information systems); and "infotainment" and comfort devices (entertainment, Internet access and communications systems).

3.1 Behavioral Adaptation

The introduction of new artifacts means that new tasks will appear or the previous ones will change or even disappear. Therefore, design should accommodate these changes either by shaping the interface or by providing instructions and training. In more complex situations, these changes take some time to occur in consequence of the time users require to adapt to the new artifact and the modified task. The duration of this process depends on the system complexity, the frequency of use, the ease of use, etc [21]. Besides the adaptation to the new conditions, there is a previous precondition for the system use: user acceptance, which means that the systems will have to be bought, used and trusted. Different studies reported by Davidse [20] refer that in-vehicle technologies will be accepted by older drivers if the systems fit their needs in terms of safety and mobility. Furthermore, the systems design is a main request for their actual positive effects. Although ITS technologies can play a significant role in offering timely alerts, an increased sensitivity to the needs of older drivers can make these technologies even more effective.

The study of the impact of ITS on road safety is a major concern due to increasing complexity they bring about to the driver although the safety goals presiding to the design and deployment of their applications. In general terms, the safety impacts of ITS depend on the extent to which they support user's needs and are compatible with human capabilities and limitations. Actually, there are risks associated to the use of ADAS and IVIS: both can cause distraction, overload and confusion, requiring behavioral adaptation. In addition, these systems increase mobility and, consequently the drivers' exposure to hazards [22]. Some medium or long term effects like loss of skill might occur (e.g. a driver can become dependent on a navigation or collision warning system to make the appropriate decision). Therefore, the systems appropriation by the driver and behavioral adaptations regarding the use of ITS by particular groups of drivers represent some of the most relevant research needs in the field of ITS aiming at improving the systems design and establishing regulatory policy.

The term behavioral adaptation has emerged to refer to those behaviors which may occur following the introduction of changes to the road-vehicle-user system and which were not intended by the initiators of the change ([23]; p.23). This OECD report concluded that road users adapt their behavior to changes in the road transport system to increase their mobility and thereby reduce the safety impact of the change. Several studies on drivers' behavioral adaptation in response to ADAS have provided a diversity of results: (1) Behavioral changes sometimes occur and sometimes not, (2) they affect different aspects of behavior, and (3) they differ in magnitude and direction [24] [25] [26] (cited by Davidse [27]).

Apparently, behavioral changes evolve from the complex interplay of the following factors:

1) They depend on the system under investigation and so, on the type of driving function supported by the system, and hence influence driver's control processes in different ways [28]. Behavioral adaptation was also found to be mediated by changes in drivers' trust [29], situation awareness [30] [31], fatigue [32] [33], mental workload [34] , and perceived risk [35]. Adaptation occurs in a specific context, which refers to the driving situation and the related driving task demands, along with the travel conditions (purpose, duration, etc.) and refers to the social and cultural background (driver population needs, habits, attitudes, legislation, etc.).
2) Behavioral adaptation is influenced by individual driver characteristics, such as driving experience, age, gender, personality traits, attitudes and motives [36] [37].

However, many of these systems are still under development and not much research has been done on user acceptance and behavior adaptation. As a result, little can be said on whether these systems will actually be used by older drivers and will actually improve their safety. Older drivers are known to be very cautious and to drive only in controlled, safe and familiar environments. For them, a navigation system and/or a collision alert system have the potential to be useful in critical situations such as driving in non familiar environments or making a left turn at an unprotected intersection. However, there are some questions arising: 1) Following a period of adaptation, can in-vehicle systems be capable of changing their travel behavior towards driving and encourage them to drive more kilometers outside familiar areas? 2) Will the older driver rely too much on the system, becoming dependent on it and, due to the age-related declines of cognitive functioning, will lose some driving skills? If there is insufficient knowledge regarding behavioral adaptation, particularly concerning older drivers, much less exists regarding long-term effects on safety and driving skills.

3.2 From HMI to HMC

When performing a task, the human operator mobilizes different cognitive functions in order to maintain his/her cognitive stability: anticipation (preparing the reaction on the basis of the perceived information, existing knowledge and experience), interaction (reactions to an external stimulus following a previous intention or planning) and recovering (conscious actions following a diagnosis of the situation) [38]. Being the interaction centered on the subject's reaction to perceived stimuli, the interface quality remains a key point with its properties of friendliness, usability, transparency, etc. These attributes have a great importance for a perfect coupling human-machine but they are not sufficient to ensure the success of the user's actions, particularly in complex and dynamic situations. Actually, the relationship between humans and machines has evolved from a simple human-machine interaction (HMI) in which the user fully controls the machine onto more complex and dynamic interactions in which the machine processes information. In these cases, the situations are not fully controlled by the user and so, they are affected by uncertainty. Therefore, in order to manage the risks due to uncertainty, some degrees of freedom must be maintained to allow the humans and the machine to adapt to unforeseen contingencies [39] [40].

In an automated process, the machine replaces totally or partially the human to perform the task. Considering the logic of human-machine coupling, there is a cooperative relationship based on a match between the human and the machine. In this case, the technology assists the user in the task performance. In the case of driving a vehicle equipped with in-vehicle advanced technology, there is a functional cooperation between the driver and the technology to perform the driving task in a highly dynamic and uncertain environment. For a common use, the driving task is not completely automated, being the driver the element of the system who makes the final decision. Anyway, this is clearly a dynamic situation where the assistance on the driving situation diagnosis and the information or alerts provided by the system are based on a functional cooperation, allowing for an improve in safety and travel efficiency.

The assistance to the driver can be provided by different kinds of ITS: information systems (navigation, alert, traffic information, etc.), automated systems (automatic control of the vehicle) and cooperative technologies (co-pilot) [41]. A co-pilot technology is supposed to analyze the context and adapt the assistance to the driver according to the diagnosis of the situation. It can be said that driving a vehicle equipped with in-vehicle technology involves a complex human-machine relationship to perform the driving task at its different levels – strategic, tactical and operational. Being a dynamic and complex task, driving is characterized by uncertainty as it is partially controlled and is also risky as the cost of errors can be very high.

Therefore, the introduction of a new technology into the car will not necessarily represent an improvement, particularly to older drivers, as most in-vehicle systems require the driver to change the behavior patterns that have served them for decades. This change may be difficult, and the need to adopt new behaviors may deprive older drivers of one of their main advantages - the extensive driving experience they have acquired over the years. The notion that a device makes sense on the drawing board does not ensure that it will have the desired effect as it is introduced into the car. In this context, the issue is the integration of different functions in the vehicle, being designed so that it will avoid an increase of the driver's mental workload. When different technologies are installed in the car the systems should work together instead of fighting for the attention of the driver and giving him conflicting information. Therefore, the assistance provided by the systems should not have any negative safety consequences on other elements of the driving task or on the behavior of other drivers. Unless the systems interfaces and the forecasted interactions will be ergonomically designed, they will overload and confuse the driver, especially the elderly.

4 Conclusive Remarks and Further Research Needs

Nowadays older people rarely are familiarized with new technologies. This leads them to avoid, in a general way, the use of technological devices. Experience in a particular task performance is the main resource of older people to keep good scores in performing the same task. However, the use of experience requires some stability on the level of the technical and environmental conditions for the task performance. Regarding the driving task, that stability doesn't exist anymore as many changes occurred in the vehicles and road environment. The increasing complexity resulting from those changes narrow down the older driver's limits to develop compensation behaviors. Then, they start to avoid driving in more complex situations and will evolve rapidly to give up driving. ITS could help older drivers to extend their mobility and independent life, but the generation effect regarding the use of technological systems will lead them to avoid the system use. That's why an appropriate design of those systems and the provision of advice for purchasing and adequate training are so important issues.

The development of ITS is very recent and still is in progress. It is quite known that users do not necessarily accept innovation, mainly older people, who are more resisting to changes than younger. Sometimes, good intentions have bad outcomes. Actually, on the one hand, it is difficult to predict the way a device could affect driving, and, on the other hand, there are several reasons why a system that should improve safety and mobility can have smaller than expected benefits [42]:

- Users may not use the device correctly;
- The device can introduce a feeling of safety that can induce the person to take more risks;
- The device could not fit the specific driving characteristics of older drivers;
- The user may develop new behavioral patterns.

New behaviors might be induced by the use of an ITS. Older drivers are known to be very cautious and to drive only in controlled, safe and familiar environments. For them, a navigation system and/or a collision alert system will be very useful in critical situations such as driving in non familiar environments or making a left turn at an unprotected intersection. However, following a period of adaptation, can in-vehicle systems be capable of changing their behavior towards driving and encourage them to drive more kilometers outside familiar areas? Or will the older driver rely too much on the system, becoming dependent on it and, due to the age-related declines of cognitive functioning, will lose some driving skills? Actually, a cognitive under-stimulation in terms of collecting and memorizing spatial information could lead the older driver to a great dependence on a route guidance system, making the person unable to drive without that information. The same may occur by the use of a collision warning system, which could affect situation awareness. Therefore, the induced behaviors by the systems use should be studied in order to prevent potential decreases in fitness for driving. For each system, the induced behaviors by its use and the side effects on driving behaviors and attitudes should be identified in order to develop adequate countermeasures.

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