Visual and Auditory Interfaces of Advanced Driver Assistant Systems for Older Drivers

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Abstract. Advanced Driver Assistant Systems (ADAS) are assumed to support drivers in critical traffic situations. This is especially important for older drivers and also drivers with disabilities, whose physical and cognitive resources are limited. An electronic intersection assistant was developed and implemented in a driving simulation setting. Independent variables were users' age and output modality. The utility of visual and auditory interfaces was examined and compared to a control group which was not assisted. Dependent variables were speed control, accuracy of lane tracking and users' acceptance. Older adults drove significantly slower, but equally accurate than younger drivers. When no assistance was present, driving performance was superior than in both assistance conditions. The visual interface had a lower detrimental effect than the auditory ADAS which had the strongest distracting effect. In contrast to performance outcomes, the auditory interface was rated as more helpful by older drivers compared to the visual interface.

Keywords: Advanced-Driver-Assistance; intersection assistant, cognitive load, driving performance, older drivers.

1 Introduction

Even though public transport is advancing in many cities still, the automobile is an important means of conveyance to access services. This is specifically essential for older adults in order to participate actively and independently in social living. However, drivers aged 65 and older have the second highest accident rate and an increased crash risk [7]. The profound demographic change with more than 20% of older drivers over 65 years in 2020 imposes considerable demands for automobile technologies, which support older drivers while driving. In recent years, commercial advanced driver assistance systems (ADAS) have been increasingly implemented into cars. Beyond route information services, the devices also cover car functionalities and telecommunication services. Though ADAS technologies are assumed to be helpful for all drivers, they *could* specifically address the needs of older drivers, compensating age-related decreases and enhancing the

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driving safety. This is of particular interest in cognitive demanding traffic situations, as intersections [4]. In these critical situations older drivers and those with disabilities are especially penalized as they are known to have limited cognitive resources to process complex and large amounts of information, to time-critically react and to cope with multitasking demands [6,11]. However, the development of usable interfaces, which actually support older drivers, is sophisticated out of several reasons. (1) Ageing itself is not a uniform, but a highly differential process: Not only the onset of ageing processes and the extent of the cognitive and sensory slowing down varies considerably across humans [1,3,5, 15,18,19,20], but aging effects can also be compensated by experience and technical expertise [3,19,20]. (2) From a cognitive point of view, driving itself is a complex multitasking demand especially for older drivers. As drivers have to process information from multiple sources in order to maintain safe vehicle control [2,8,16] and, at the same time, to follow traffic demands, additional information delivered by the ADAS may represent an extra workload. (3) A third critical factor is the ADAS modality. When information is presented visually, attention has to be shared between the visual control of traffic and the ADAS information [16,17]. The concurrent processing of tasks, which share common resources [17] leads to performance losses, especially for older drivers [11,14]. Information in the ADAS may also be presented auditorily. Visual and auditory information can be timeshared more effectively [16] as they rely on different perceptual channels. However, auditory presentation of side information may also have detrimental effects [10,17]. The alerting effect caused by the sudden onset of auditory information may distract drivers and attract attention away from the primary task (driving) to the processing of the auditory information. In addition, as the auditive information needs more processing time than visual information, working memory load is high in order to memorize the information.

Overall, the study's aims were twofold: One aim was directed to the design of ADAS systems, which are assumed to support older drivers in cognitively demanding traffic tasks. The second aim was an experimental evaluation of the system's utility for older drivers in terms of driving performance and acceptance.

2 Development of an Intersection Assistant

The experiment was carried out in a driving simulator environment, composed of a truncated Mercedes car with an automatic gear shifting placed in front of a projection screen (Figure 1, left). The car functioning (steering, accelerator and brake pedal) was simulated and no tactile feedback was given. The screen had a size of 7.30 x 2.80 m and a resolution of 2048 x 768 pxls. The graphics were projected by two video projectors placed on two stands. The simulated environment was created with Pelops©, a software developed at RWTH Aachen University, which combines vehicle, traffic technical and driver models and therefore allows recording online all interactions that occur between driver, vehicle and traffic events. The visual display was presented on a flat screen (800 x 600 pxls) in the midconsole of the simulator car. The auditory information was presented through the simulator speakers. For the visual condition, the information appeared in the display of the midconsole, which otherwise was kept dark. In the auditory display, information was faded in timely so that the spoken information was finished when participants entered the intersection. The appropriate moment, when the visual and auditory information was given, was determined in several pre-experimental studies. In order to provide for an optimized visual communication in the car, the sign-production-method was used [9] in a pre-study. Participants were requested to picture symbols on the base of verbal referents. The sign-production method assumes that visualizations designed by users have an increased chance of being correctly interpreted by them. 36 participants (18 males, 18 females, 24-57 years) were told that an interface of an intersection assistant had to be created, which informs drivers about the volume of traffic in the next intersection and also the right of way regulation. The majority (93%) of participants sketched a crossing in combination with a traffic sign. The right of way regulation was pictured mostly by a traffic sign (70%), in 30% by arrows. Other road users were predominately pictured by symbolized cars (78%), but also by arrows. On the base of these drawings, the visual interface was designed and implemented (Figure 1, right).

Fig. 1. Left: (in)side view of the car; Right: Visual interface of the ADAS

3 Experimental Evaluation of the Intersection Assistant

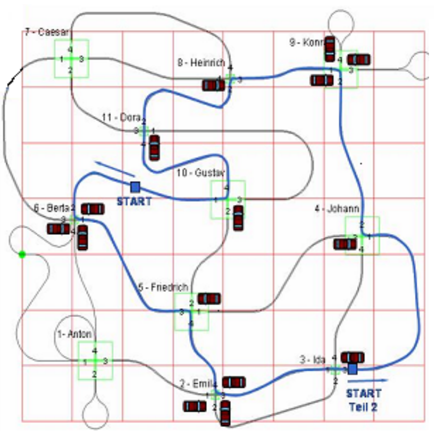
3.1 Variables

Independent variables: The first independent variable was users' age, comparing younger and older drivers. The second variable referred to the ADAS modality: (1) Information was presented visually on a display in the midconsole when participants approached the intersection. (2) Information was presented acoustically 20s before the intersection, considering the longer processing time of auditory information. (3) A control condition without assistance. A third independent variable referred to gender effects. *Dependent variables*: Among performance measures, speed control (km/h) and accuracy of lane tracking (radian, rad[1]) were examined. After completing the driving, drivers were asked to rate if the assistance was helpful for them or not.

[1] Radian is a unit of angular measure equal to the angle subtended at the center of a circle by an arc equal in length to the radius of the circle. To give an example: A rad of 0,05 equals a steering angle accuracy of 2.9 deg.

3.2 Driving Task

An urban environment was chosen, in which nine intersections with different volume of traffic and priority rule had to be passed (Figure 2). To assure that all participants covered the same distance and task/route difficulty, drivers were directed to specific destinations (“ZOO”), which were indicated as signs in the environment. In order to familiarize participants with the properties of the simulation, a training route had to be completed. They were instructed to drive naturally and to obey to traffic rules, to keep speed limits (50 km/h) and to track the lane appropriately.



Inter-section	Priority rule	Driving direction	Volume of traffic
Berta	Give right of way	Left turn	Three cars from three directions
Friedrich	You have right of way	Right turn	One car ahead
Emil	give right of way	Left turn	Three cars from three directions
Ida	You have right of way	Straight on	One car, ahead
Johann	You have right of way	Right turn	One car, ahead
Konrad	Give right of way	Left turn	Three cars, three directions
Heinrich	You have right of way	Left turn	One car, ahead
Dora	Give right of way	Straight on	One car, ahead
Gustav	Give right of way	Right turn	One car, ahead

Fig. 2. Left side: Experimental route with nine different intersections; Right side: Priority rule, driving directions and volume of traffic at the different intersections

3.3 Participants

50 participants with valid drivers’ licenses took part in the study. They had answered to announcements in the newspaper. 25 younger drivers (20-35 years) and 25 older drivers (50-78 years) took part. 16 participants (8 young (M=26.7); 8 older (M=61.2) were assigned to the “auditory interface group” and 17 participants (9 young (M=28.1); 8 older (M=61.8)) to the “visual interface group”. Finally, 17 participants (8 younger (M=26.1) and 9 older (M=63.1) formed the “control group” (no ADAS). Driving experience was higher in older than younger drivers ($F(1,44)=76.5$; $p<0.00$). 68% of older adults used the car daily (younger 52%), 24% about three times a week (younger: 28%) and 8% once a week (younger: 20%). Gender differences were not found respecting to driving experience.

4 Results

Results were analyzed by MANOVA assessing effects of interface modality, age and gender on speed control (km/h) and lane tracking accuracy (rad). Significance level was set at 5%. For a detailed insight, intersections were distinguished from the sections in between (free routes). Before driving outcomes are reported, it should be considered how a “good” or “appropriate” driving may be defined. Participants were instructed to show a sensible and responsible driving behavior, to drive fluently, but to take also safety matters into account. For free routes, we would expect a higher driving speed (within speed limits). The speed should drop considerably when drivers cross or turn at intersections due to the higher workload and attention demands.

Effects of the presence of an ADAS System: It was analyzed if any ADAS (independently of modality) leads to a better performance compared to the control group. A significant omnibus effect was found for both, intersections ($F(1,41) = 3.6$; $p<0.05$) and free routes ($F(1,41)=4$; $p<0.05$). In intersections, driving speed was slower ($M=21.4$; $SD = 1.4$) when assisted by ADAS than without ADAS ($M=26.4$; $SD=2.5$). The driving speed on free routes was generally higher than in intersections, but it was still lower than without ADAS ($M=41.9$; $SD=2.2$). For accuracy no differences between groups were found. Lane tracking accuracy was lower in intersections than on route sections without crossovers.

Effects of output modality: For intersections, a significant effect of output modality ($F(2,76)=3.4$; $p<0.05$) was found. The F-tests showed the effect of modality to be significant for speed ($F(2,38)=5.9$; $p<0.05$), but not for accuracy. Post-hoc tests revealed the auditory ADAS to result in a significantly lower driving speed ($M=19.1$ km/h) compared to both, the visual ADAS ($M=23.4$ km/h; $t=-1.2$; $p<0.05$) and the control ($M=26.3$ km/h); $t=-2.0$; $p<0.05$). The visual condition was not significantly different from the control ($t < 1$; n.s.). Results are visualized in Figure 3.

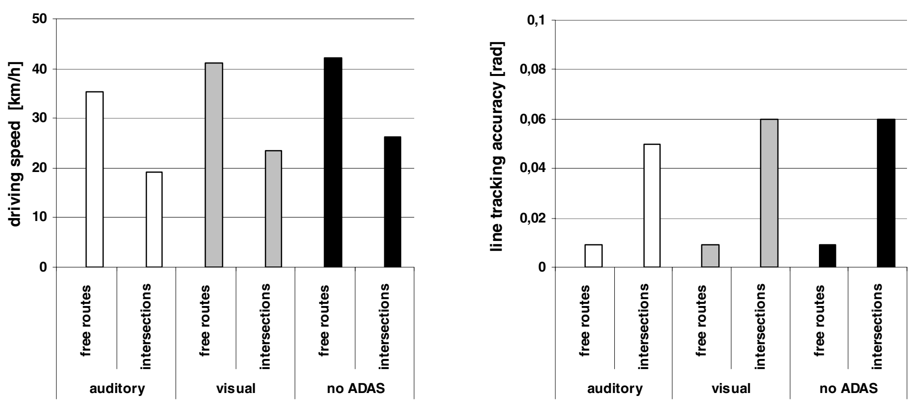


Fig. 3. Effects of ADAS modality on driving speed (left) and accuracy (right)

The effect of modality was also significant for free routes ($F(2,76)=2.8$; $p<0.05$). Again, the auditory interface resulted in the lowest driving speed ($M=35.3$ km/h), followed by the visual interface ($M=41$ km/h) and the control ($M=42.1$ km/h). Line tracking accuracy was equally high for all conditions. Post-hoc statistics revealed the auditory interface to result in a significantly lower speed than the visual interface ($t=-1.6$; $p<0.01$) and the control ($t=-1.9$; $p< 0.01$). As expected, driving speed and accuracy was lower in intersection areas compared to the routes in between, hinting at a higher driver workload at intersections resulting in more careful driving.

Effects of age: For intersections, a significant omnibus age effect was found ($F(1,37)=9.3$; $p<0.05$). Age affected the driving speed ($F(1,38)=19.1$; $p<0.05$), but not line tracking accuracy. The same was found for free routes: Age had a significant omnibus effect ($F(1,37)=11.7$;$p< 0.05$), and for driving speed ($F(1,38)=23.7$; $p<0.05$). Younger adults drove faster throughout (intersections: M=26 km/h); free routes: M=44 km/h) compared to older adults (intersections: M=20 km/h; free routes: M=36 km/h). No age differences were found for line tracking accuracy, and no interacting effects of modality and age were revealed (Figure 4).

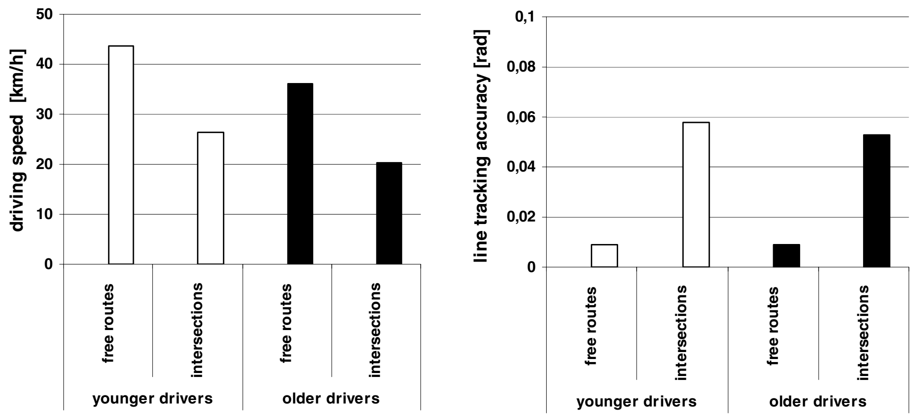


Fig. 4. Driving performance in both age groups (left: speed; right: accuracy)

Effects of Gender: Significant gender effects on driving speed was found for intersections ($F(1,37)= 6.2$; $p<0.05$) and free routes (F $(1,37)=6.6$; $p<0.05$). Women drove with 28 km/h (intersection: M=20.2 km/h; free routes: M=36.7 km/h), whereas men drove faster throughout, reaching an average speed of 33 km/h (intersection: M=25.2 km/h; free routes: M=41.7 km/h). No gender effects were found for line tracking accuracy as well as no interacting effects of gender, age or ADAS type.

Acceptance: The majority of older adults (80%) evaluated ADAS assistance as helpful. Younger drivers in contrast were ambiguous (helpful:45%; not helpful:55%). Older adults clearly preferred the auditory over the visual interface. Younger adults, had no explicit bias towards the one or other interface. While younger adults were simply fascinated by technology developments, older users expressed some cautionary notes. They basically conceded that ADAS technologies have the potential to support older drivers compensating for age-related declines. However, they emphasized that they would not accept technologies, which increasingly replace the cognitive control of drivers and pushed the claim to keep the role as decision-making authority in the car as long as they are able to.

5 Discussion

As intersections are known as cognitively highly demanding traffic situations with an increased crash risk, an electronic intersection assistant was created and implemented, which only comes into fore just before drivers entered an upcoming crossing. The assistant recalled the priority rule and signalized the volume of traffic. In order to provide for a usable interface, a user-centered participatory development of the visual and auditory interface was adopted. Different from previous studies [8,11,16,17] we focused not only on performance outcomes, but also considered users' acceptance.

Older drivers showed, overall, a lower driving speed, but an equally high line tracking accuracy compared to younger drivers. As all participants kept driving speed within speed limits, the speed decrease in combination with a sufficient line tracking accuracy may be interpreted as "lower" performance. The age effect confirms previous findings and can be referred to lower cognitive, sensory and psychomotor abilities [1,3,5,18,19,20], which was not compensated by higher driving expertise. In addition, older adults' lower driving speed may also be attributed to a generally more cautious driving style, which was not restricted to cognitively demanding intersection areas, but was also present throughout. It should be noted though that the older group had an equally high line tracking accuracy, what confirms that older adults prefer the accuracy over the speed component in tasks with increasing difficulty [18,20].

The question, whether drivers benefit from assistance at all and whether the positive effect of assistance weighs stronger than the negative effect due to extra workload, can be clearly answered. Any assistance in the car represents an extra workload what can be taken from the fact that driving performance in the group without assistance was generally superior (faster but equally accurate). Thus, we have to concede that ADAS systems also bear a considerable risk to deflect drivers' attention from the primary task, the driving itself. One should take into account that the ADAS in our study only had one single function, which, in addition, was highly relevant for accomplishing the driving task. Thus, it has to be assumed that current information systems which usually provide a much larger complexity of functionalities can be a considerable safety risk when used while driving.

Another major question was which interface modality might be more useful for older adults' driving performance. Two different expectations stood vis-à-vis: According to the resource model [16,17], the visual interface should have the more negative effect on performance as two visual tasks compete for visual attention, which cannot timeshared to more than one place at a time. On the other hand, there was empirical evidence that the auditory information presented also has detrimental effects [17], as the processing of auditory information needs specific attention and extra charges working memory capacity. The findings revealed that the auditory interface led to stronger performance losses compared to the visual interface, independently of route characteristics and users' age. In the contrary to performance outcomes, older drivers rated the auditory interface as more helpful than the visual interface. The reason for the mismatch between acceptance, perceived usefulness and performance cannot be resolved on the base of the present data. However, as users' acceptance is a sensitive variable for the success of any technology, further studies should validate this outcome in another setting. This is especially necessary to examine the utility and acceptance for drivers older than 80 years which might be more hampered by age- and health-related restrictions and which might therefore depend on assistance systems more strongly in order to be able to participate from mobile and traffic services.

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