Comparison of a Head-Down Display (HDD) versus a Head-Up Display (HUD) in a simulated driving task: effects of ageing

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Abstract: A complex human-machine interface of an In-Vehicle Information Systems (IVIS) can cause the eyes to be diverted from the road for a long time, causing a threat to traffic safety. In the current dual task experiment a Head-Down Display (HDD) and head-up display (HUD) were used during a simulated driving task, to evaluate potential benefits of HUDS, and to investigate whether effects of head-up presentation were similar in different age-groups. A visual search task was used as a surrogate-IVIS. The results showed that displaying the visual search task on a HUD had a positive impact on driving performance. Young subjects improved their driving and visual search performance, while older subjects only improved their search performance by making fewer errors. These findings have consequences for the design and deployment of HUDs for different age groups.

Keywords: dual task, traffic, ageing, visual search

1. Introduction

A number of studies have demonstrated the benefits of head-up displays (HUDs) while driving as compared to the similar information displayed on a head-down display (HDD). These benefits were expressed in tracking performance in the primary task, responses to events outside the car and responses to display information, but research has shown that the benefits of HUD may be reduced or reversed in response to unexpected events and in conditions of high workload (e.g. Horrey & Wickens, 2004; Graham, 2007). Few studies have compared the benefits of HUD versus HDD with effects of healthy cognitive ageing. Ageing is an important issue when looking at the implications of HUD usage because the age of the drivers covers a far wider range than the military pilots for whom the HUDs were initially developed. Kiefer (1991) found no significant differences between age groups when a speedometer was presented on a HUD compared to the usual speedometer for speed and scanning behaviour. Another study found an overall decreased performance for elderly drivers, but no interaction with display location and age. Thus the elderly showed the same improvement when the information was presented on a HUD as young drivers (Gish & Staplin, 1995). In both studies the workload was

relatively low, and reading of the speedometer in the windscreen was highly practised and involved standardized information. The aim of the current experiment was to increase workload to by increasing the complexity of the visual secondary task based on the approach of the HASTE project (Carsten & Brookhuis, 2005). The performance using the HUD was compared with the HDD. The expectation was that both age groups will improve their driving performance and visual task performance in the HUD condition. We were in particular interested in the elderly drivers. With the HUD there is no need to divert the eyes from the driving task; hence time sharing between the two tasks should become less demanding.

2. Method

Twenty young participants aged between 20 and 29 years (M=23.3, SD=2.5) and twenty older people between 50 and 70 years (M=60.2, SD=5.0) were tested. All participants had had their driver's license for at least 2 years (young participants: M=5.3, SD=2.3; old participants: M=39.9, SD=9.9). Participants had normal or corrected to normal vision. In each group half of the participants were female.

The driving task was a simulated track consisting of a straight three-lane road (Lane Change Task, Mattes, 2003). With the gas pedal pressed maximally the participant drove a distance of 3 km at a constant velocity of 60 km/h. There were 18 signs along each track indicating the lane the participant had to change to as soon as the sign was identified. The visual search task stimuli had a set size of nine arrows which were either red or green and pointed in different directions. The visual search task was presented on HUD or a HDD. The target arrows were an upward-pointing green arrow and a right-pointing red arrow; only one target or no target was present per trial. The probability of a target arrow being present was 50%. The target appeared at a random location. Participants were instructed to press a right button if a target was present, and a left button if no target was present. The duration of the visual search stimuli was 3500 ms combined in 8 blocks, each consisting of 40 trials. Participants were asked to react as quickly and accurately as possible. In the dual task blocks the participant was instructed to give first priority to the driving task. The training of the visual search task continued until the participants reached a minimum of 80% correct trials. After each block self-reports of invested effort were rated with a German version of the Rating Scale of Mental Effort (RSME; Zijlstra, 1993).

The simulated driving was presented on a 67-inch CRT screen (Barco simulation products Baron). For tracking a Logitech gaming steering wheel was used with gas and brake pedals. For the HDD the visual search task was displayed on a 15-inch LCD screen that had a distance of 1.45 m with a visual angle of 18°. This LCD screen was located in front of the CRT screen (distance 1.96 cm, visual angle 38° x 29°) without blocking the sight on the road. Additionally, a HUD was created by using a half transparent mirror, which was located in front of the participant with an angle of 45°. During the whole experiment the participant looked through the mirror, but only in the HUD condition a semi-transparent image of the visual search task was visible for the participant at the horizon of the driving task. For this the visual search task was presented by an additional 15 inch LCD behind the participant and this display was reflected into the visual field of the participants by the half transparent mirror (same stimulus size like in the HDD). Seat height was adjusted individually to keep the angle of the eyes equal between participants. The measure of driving performance was the deviation between a normative model and the participants' actual course on the track, further performance of the secondary task were analysed.

3. Results

Elderly participants drove worse than young participants when they had to combine the driving task with the visual search task. There was no difference in driving performance between HUD and HDD. The performance of the young participants was also decreased with the secondary task on the HDD compared to the baseline i.e. driving without the additional task. However, young participant were able to drive at a baseline level while performing the secondary task on the HUD. Reaction times (RTs) were high when the visual search task was displayed on the HDD. When the secondary task was transferred to the HUD young participants again had an improved performance, while the RTs of elderly participants remained equally high at both displays (Figure 1). However, the error rate improved drastically for the elderly participants and the HUD caused an reduction of their error rate from 37 to 24%. Young participants also made fewer errors and reduced their error rates from 22 to 15%. Although performance of the secondary task improved with presentation on the HUD, it still suffered from a dual task decrement for both age groups. Participants reported more effort when using a HDD than with a HUD, but there were no effects of age group for the RSME.

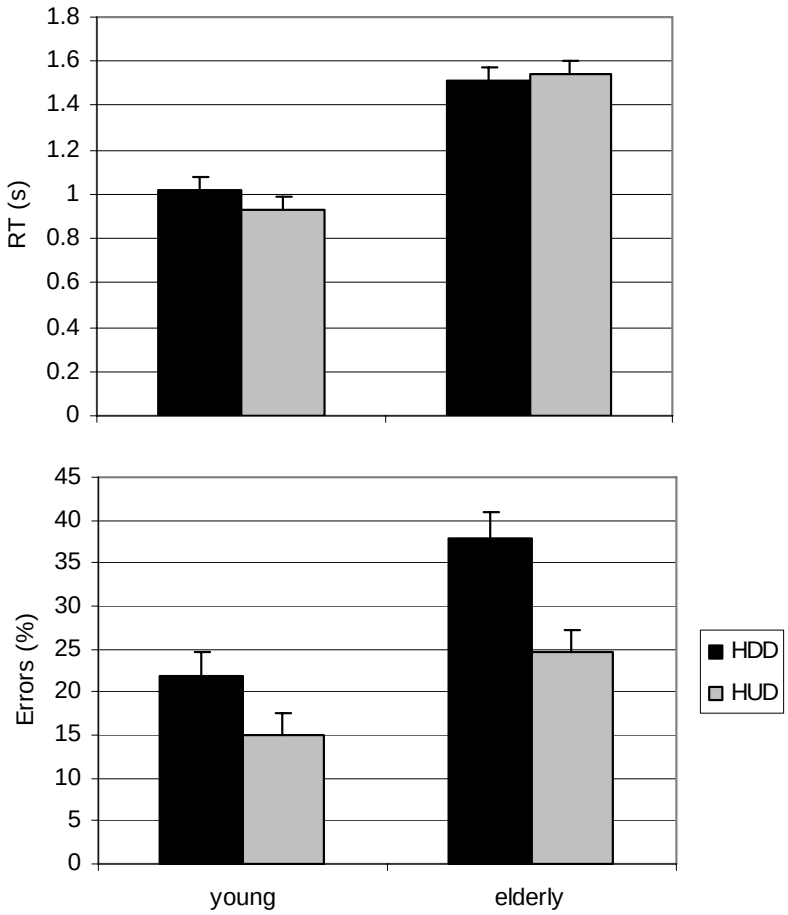

***Figure 1**: Mean reaction time and error rate as a function of age and display type.*

4. Discussion

Overall there was a clear effect of age; elderly participants had a less accurate driving performance, had longer RTs and made more errors. The error percentage was increased drastically when the driving task was combined with the visual search task on the HDD, especially elderly participants made a large amount of errors (38%). Error percentages were still high, but improved when the visual search task was presented on the HUD rather than the HDD, for both young and elderly participants. Thus, providing information by a HUD seems to be beneficial for performance, at least for the secondary task. The HUD had a positive effect on performance in the dual task condition. However, only young participants improved their driving performance and reaction time on the visual search task compared to driving with the HDD. Elderly drivers showed an improvement with HUD but this was only visible in a reduction of the error percentages in the search task, in which younger participants showed improvement as well. In contrast to the previously mentioned studies which found the same improvement of performance for several age groups with HUDs (Gish & Staplin, 1995; Kiefer, 1991) the current study shows that the usage of HUDs can have different effects for age groups. This could be caused by the high visual complexity of the stimuli used in the current study which made the secondary task more demanding. Indications for the greater influence of visual complexity for elderly drivers were found in a driving simulator study (Merat, Anttila, & Luoma, 2005). A systematic increase of the visual complexity of a secondary task caused worse lane keeping behaviour and a greater reduction of speed for elderly drivers than for young drivers. Driver age is an important factor to be considered when designing the display for in-vehicle use. Elderly drivers' performance was less erroneous, but they did not benefit as much as younger drivers when the task was presented on a HUD. And even though information presentation on a HUD is more advantageous it may still cause dual task decrements both for young and elderly drivers.

5. References

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