LANE POSITION HEAD-UP DISPLAYS IN AUTOMOBILES: FURTHER EVIDENCE FOR COGNITIVE TUNNELING

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The benefits associated with the implementation of Head-Up Displays (HUDs) in aircraft have promoted the use of this technology in automobiles. These benefits, however, have been shown to come with concomitant performance costs. Specifically, aviation and motor vehicle research has shown that HUDs produce cognitive tunneling effects whereby an operator’s attention is captured and held by the HUD symbology such that it cannot be directed elsewhere. The cost of cognitive tunneling could be more severe for driving than for flying given that driving environments are typically more densely populated than they are for flying. For this reason, research on the effects of HUD-induced cognitive tunneling in automobiles is important. The current experiment explored the effects of a lane position HUD on driving performance. The results benefits and costs: the HUD improved lane position maintenance, but impaired speed monitoring.

Introduction

Head-Up Displays (HUDs) were originally developed as a tactical aviation technology, but have more recently been adopted for use in automobiles. In both domains, the rationale for using HUDs is that they allow operators (pilots, drivers) to monitor their instrumentation while keeping their eyes on the external scene. In doing so, operators are putatively less likely to miss events in the external scene. This potential benefit of HUDs is especially important in the context of driving insofar as potentially critical events may be missed if the driver’s eyes are “off the road” to view in-cabin instrumentation.

Research has shown that automotive HUDs can improve driving performance. For example, the availability of a HUD resulted in quicker responses to sudden changes in the external driving scene (Srinivasan, 1997) as well as better detection of speed limit changes and faster responses to critical events (Liu & Wen, 2004).

However, benefits of automotive HUDs are not unequivocal and often come with associated performance costs. For example, Wolffsohn, McBrien, Edgar and Stout (1998) found that a digital HUD showing vehicle speed increased reaction times to braking in a lead vehicle. Hagen, Brown, Herdman and Bleichman (2005) showed that a digital speed HUD improved speed monitoring, but impaired lane position monitoring. In sum, HUDs improve performance on certain driving tasks but impair performance on other tasks (see also Ward & Parkes, 1994 Wickens & Long, 1995).

Performance tradeoffs with HUDs make it important to prioritize the various driving parameters that require monitoring. Although speed monitoring is important, the failure to monitor lane position could prove disastrous in that it may lead to serious head-on collisions under certain conditions. Accordingly, the present experiment examined costs and benefits associated with a lane position HUD. Participants drove a high-fidelity, fully configured driving simulator through a realistic scenario. Two critical conditions were compared. In the no-HUD condition, only the standard in-cabin instrument panel was used. In the HUD condition, the instrument panel was augmented with an analogue HUD showing the vehicle’s lane position relative to the boundaries of the lane.

Methodology

Participants. Sixteen participants were recruited from the Carleton University community with the requirement that they had at least 1.5 years of driving experience. They were compensated with either $15 or 1.5 experimental credits toward an introductory psychology course.

Equipment. A high-fidelity, fully configured, fixed-base DriveSafetyTM 500c driving simulator was used. The simulator was mounted in front of five flat-screen displays subtending 21.8° of vertical visual...
angle and 150° of horizontal visual angle. Computer-generated engine noise and external noise of passing traffic was presented on speakers located both inside and outside of the cabin.

Driving Scenario. The driving scenario consisted of a two lane roadway (one lane in each direction) with curves and straight sections in a rural setting with oncoming traffic. Each lane was approximately 3.2 m in width. Posted speed limits were 45, 55, or 65 mph.

Design. A 3 (Speed Limit: 45 vs. 55 vs. 65 mph) X 2 (Visibility: good vs. poor) X 2 (HUD: on vs. off) repeated measures design was used. Each participant was tested individually and experienced each of the 12 conditions.

Dependent Variables. Lane position monitoring was measured as the lateral deviation of the vehicle from the centre of the lane. Speed monitoring was measured as the difference between vehicle speed and the posted speed limit. Both measures were recorded at 60 Hz.

Procedure Participants received a verbal briefing of their driving task and then completed a practice session. They were instructed to obey posted speed limits and to maintain a central lane position. The experimental session immediately followed the practice session and was approximately 90 minutes in duration.

Results

Lane position monitoring. Lane deviation data recorded during the first 20 seconds of each of the 12 experimental conditions were excluded from analysis given that participants had to adjust to the new driving conditions (e.g., change their speed). The remaining data were submitted to a 3 (Speed Limit) x 2 (Visibility) x 2 (HUD) repeated measures Analysis of Variance (ANOVA).

Of primary interest was evidence for an overall HUD benefit, $F(1, 15) = 14.1$, $MSe = 0.004$, $p < 0.005$, whereby mean lane position deviations were significantly smaller in the HUD condition (0.35 m) than in the no-HUD condition (0.38 m).

There was also a main effect of Speed Limit, $F(2, 30) = 11.8$, $MSe = 0.003$, $p < 0.001$, where mean lane position deviations were greater at the 65 mph (0.39 m) than at either the 55 mph (0.36 m) or 45 mph (0.34 m) speed zones. The main effect of Visibility approached significance, $F(1, 15) = 3.9$, $MSe = 0.02$, $p < 0.07$: as expected, mean lane position deviations were greater when visibility was poor (0.38 m) than when it was good (0.35 m).

A Speed Limit x Visibility interaction, $F(2, 30) = 3.8$, $MSe = .004$, $p < .05$, showed that the HUD had a larger benefit on lane position maintenance at 45 mph and 65 mph than at 55 mph. This interaction was not predicted a priori and is therefore not be discussed further. No other interactions were significant.

Speed monitoring. As with the lane position data, the speed data recorded during the first 20 seconds of each of the 12 experimental conditions were excluded from analysis. The remaining data were submitted to the same 3 x 2 x 2 ANOVA used for the lane position monitoring data.

Of primary interest was evidence for a HUD cost, $F(1, 15) = 7.6$, $MSe = 0.69$, $p < 0.05$, whereby mean speed deviations were significantly greater in the HUD condition (3.4 mph) than in the no-HUD condition (2.7 mph).

There was also a main effect of Speed Limit, $F(2, 30) = 4.5$, $MSe = 1.55$, $p < 0.05$, where mean deviations from the posted speed were greater at the 65 mph (3.8 mph) than the 55 mph (2.3 mph) and the 45 mph (2.7 mph) speed zones. The main effect of Visibility and the two-way and three-way interactions were not significant.

Discussion

The central finding in this experiment is that an analogue lane position HUD improved lane position monitoring, but impaired speed monitoring. This pattern of results mirrors Hagen et al.’s (2005) finding that a digital speed HUD improved speed monitoring performance, but impaired lane position monitoring. The results from the present experiment are consistent with the claim that there are performance tradeoffs associated with using HUDs. Specifically, the current results, when coupled with those reported by Hagen et al., suggest that HUDs improve performance on ‘HUD-relevant’ tasks (i.e., tasks that the HUD is designed to address), but impair performance on ‘HUD-irrelevant’ tasks (i.e., tasks not specifically related to the information conveyed by the HUD).

Conclusion

The present results and those of Hagen et al. (2005) show that there are performance tradeoffs (i.e., costs and benefits) associated with using HUDs. These tradeoffs should be considered when deciding what information should be displayed on an automotive
HUD. It is proposed here that a lane position HUD may be of greater value than a standard digital speed HUD in terms of driver safety.

References


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