
Measures of Visual Distraction in Augmented Reality Interfaces

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Abstract

The NHTSA guidelines for nomadic and aftermarket devices [1] include Augmented Reality Head-Up Displays (AR HUDs). However, the measures for the distraction potential of these systems are based on the traditional eyes-off-the-road paradigm. AR HUD interfaces are designed to keep the eyes of the driver towards the road ahead. Nevertheless, messages and graphical overlays may still be distracting from crucial information. How can the distraction be measured, and how does such distraction impact on driving and situation awareness? This reflection statement discusses the pros and cons of using existing distraction measures and outlines potential approaches that take into account the unique qualities and challenges associated with AR HUDs.

Author Keywords

Augmented reality, Head-up display, AR HUD, Driver distraction, Driving simulator, Visual behaviour, NHTSA guidelines.

CCS Concepts

H.1.2. User/Machine Systems: Human Factors; H.5.m. Information Interfaces and Presentation (e.g. HCI: Miscellaneous

Introduction

The overall aim of AR HUD systems is to make driving safer, more pleasant and more convenient. One major

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advantage is that AR HUDs include the presentation of information in, or close to the forward driving scene, which should not divert drivers' gaze away from the road. Especially when the overlaid information is spatially and physiologically linked to actual objects in the road scene, distraction could be minimised and the attention directed to relevant objects.

Nevertheless, there is a strong need to understand the challenges for visual and perceptual distraction issues when using AR HUDs. Particularly, it is still necessary to quantify distractions by overlaid AR information. It is expected that the visual distraction guidelines by the NHTSA for nomadic and aftermarket devices [2] apply to AR HUDs as well, but it has not yet been established which measures are suitable, and to which degree the guidelines still need to be completed.

Visual measures

Visual distraction usually involves taking the eyes off the road [cf. 3]. Studies investigating visual behaviour while performing secondary tasks are based on the presumption that drivers face a trade-off between glances towards the secondary task activity and the road scene [e.g. 4]. AR HUDs are able to avoid drivers needing to look away from the forward road-scene. However, visual distraction may still occur, as users visually attend to the displayed information and could miss cues important to the driving task. As distraction measures based on glances completely off the road do not apply for AR HUD information, distraction needs to be measured in other ways that take into account, for example, drivers' peripheral and useful field of view.

One possibility is to measure glances at hazardous objects. Häuslschmid et al. [5] tested a windshield

display in a driving simulator study and found that, compared to traditional systems and a HUD with limited view, with the windshield display, drivers gazed longer at the leading car and other areas within the road scene. Participants also changed their visual focus less and had fewer glance counts. This can indicate efficient search behaviour. However, conclusions about the distraction potential of the windshield display are difficult to draw.

Other measures of visual distraction include the duration and dispersion of fixations. The concentration of the drivers' gaze is considered a measure of workload induced by distraction tasks [e.g. 6]. However, an AR image may also attract the gaze, completely capture the gaze (leading to cognitive tunnelling) or divert it, e.g. if too many AR elements are on the screen (known as 'visual clutter').

An ergonomic focus distance for AR HUD images is suggested to be at around 2-3m, likely to approach optical infinity for most driver's eyes and to minimize focal switching between AR HUD graphics and the scene. However, even such a distance requires drivers to refocus their eyes (e.g., via accommodation and vergence) and visual attention to and from objects in the actual roads. There are also costs associated with context switching (from AR HUD graphics to real world scene) independent of focal switching. It is not yet easily possible to measure whether drivers visually focus towards a near or far target, e.g. if transparent information is laid over distant objects. And even such measures would be limited in simulation settings (where the AR HUD focal distance may be near or equivalent to the focal distance to simulation imagery). Hence, the actual focus needs to be assumed from the

point the participant looks at in the 2-D plane, which requires very precise technology, calibration and judgement of the coder.

Situation awareness

Especially in situations with high workload and temporary uncertainty, AR displays might capture the drivers' attention away from the driving scene. For example, a HUD-based navigation arrow could distract from real hazards in the road-scene [7].

One way to measure Situation Awareness (SA) is to probe whether (other) hazards have been recognised. This can be done during driving, e.g. using a braking car in front of the host vehicle. Both braking lights and looming can activate a behavioural response of the driver [8].

Verbal protocols are suitable to explore SA, and the effects of different difficult driving situations or tasks on the mentioned themes [9]. This method is not exact, as the themes are subjective, but can offer valuable insights.

Driver performance

Measures of driving behaviour such as changes in the following distance have been employed in studies using AR HUDs [5]. Due to the proximity between the AR overlay and the lead car, the mechanisms occurring while observing the overlaid information and the lead car still need to be better understood.

Lane keeping and lateral stability can be affected by visual distraction as well, although it has been found that moderate distraction may not be reliably influencing driving performance [10]. The question is to

what degree lane keeping is affected, when information is displayed in the front as compared to locations off the road. Steering reversals pose a similar problem.

Drivers tend to reduce their speed when distracted, which may happen due to AR HUD tasks as well, so this can also be a suitable measure to include.

Measurement tasks

For the Tactile Detection Task (TDT), drivers wear a small vibrating motor (a 'tactor') attached to the lower part of the neck. Periodically, the motor vibrates with a low intensity pulse. The task of the participants is to press a button on their index finger against the steering wheel when they notice the pulse, in order to switch it off. The TDT can measure visual load, but it has been shown that the TDT is more sensitive to cognitive load [11].

The Peripheral Detection Task (PDT) is based on the detection of reaction times to, and misses of, peripheral light stimuli. For auditory tasks such as cell phone conversations, the PDT is sensitive to cognitive load [12]. For visual-manual tasks, the PDT is also sensitive to effects on visual-perceptual and manual-motor load. However, the light signals could simply be missed as the participant looks away. Whether the PDT interferes with the AR HUD information, as it is based on visual cues, or is suitable, as it measures visual distraction better than the TDT, still needs to be established.

Subjective measures

In a study by Häuslschmid et al. [5], drivers generally preferred the windshield display, except that it was considered more distracting than driving without display. Subjective measures provide cost-effective

information, but often people are not aware of how distracted they were, especially young drivers [13]. In summary, involving drivers' opinions and attitudes can add valuable data to complete results obtained with objective measures.

Conclusions and Research Roadmap

It is apparent that traditional eyes-off-road measures in their current form are likely not well-suited for distraction due to AR HUDs. Rigorous research is needed to evaluate and quantify the effects of visual distraction on situation awareness, visual and driver behaviour, supported by measurement tasks and subjective measures.

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