Investigation of Prototype Full-Windshield Head-Up Display Interface Impact On Users' Driving Patterns Under Adverse Weather Conditions

Vassilis Charissis

Glasgow Caledonian University,
School of Engineering and Built Environment,
Department of Computer, Communications and Interactive Systems
Virtual Reality and Simulation Laboratory
Cowcaddens Rd., G4 0BA, Glasgow, Scotland, UK

ABSTRACT

The paper presents a prototype full-windshield Head-Up Display interface and discusses the users' driving patterns arising from the use of a proposed HUD system, under low visibility in a motorway environment. Finally the paper offers a tentative plan of future research work.

1. INTRODUCTION

Contemporary Head-Down Display (HUD) information portrayed by automotive infotainment devices, while useful, is often ignored by the driver due to field of view limitations, typically associated with traditional instrumentation panels [1]. In its various forms, HUDs have been tentatively used in contemporary vehicles offering a number of benefits and producing various issues both in terms of application scope and popularity [2,3,4]. The produced benefits have mainly appeared in the response times that the drivers' demonstrated as infotainment data was presented directly on their field of view reducing significantly the "search and read" time spent on concurrent dashboards. Yet the experimental shape and amount of information in conjunction with different projection issues hindered the usage advantage of the HUD systems.

The proposed interface, as applied in a full-windshield Head-Up Display system, aims to improve the driver's situational and spatial awareness by considering information as it becomes available from various sources such as VANETs, GPS and other vehicular sensors [5]. Effectively the vehicle's windshield is transformed to an augmented reality display area which allows the system to present crucial information related to collision avoidance guidance to the driver in typical or adverse driving conditions [6]. Opting for a simplistic approach of interaction, the interface elements are based on minimalist visual representation of real objects superimposed on the actual environment [7].

Motivated by the above observations, this paper presents a study on the effects of driving patterns with and without the use of a prototype HUD. Furthermore the paper discusses the challenges involved in the HUD design, introduces the visual components of the interface and presents the outcome of a large scale evaluation of the system on a group of forty users, as performed using two different types of driving simulators namely Open Source Driving Simulator (OSDS) and Virtual Reality Driving Simulator (VRDS).

The rest of this paper is structured as follows; The next section presents the considerations for presenting external information through the HUD conduit. The following sections present a succinct description of the HUD interface and the observation of the human responses to the augmented reality HUD information. In turn, the implications of the choice of various symbolic information with respect to their context and human-performance is discussed and accounted for. Finally, the last section summarises the conclusions of this study and offers suggestions for future work.

2. HUD INFO CONSIDERATIONS

During an imminent collision, alternative decision-making paths become available to the driver; so many, in fact, that the number of options may be overwhelming. Markedly, the number of possible reactions is related to the number, location and speed of the objects involved in a possible collision situation. Intuitively, the options the driver considers are limited by the amount of information an average driver can process during the time to collision period. Hence, it is nearly impossible for a driver to identify, evaluate and run through the branching possibilities of a potential collision scenario and opt for a positive one. Low visibility further reduces the available time for object recognition and subsequent decision-making based on that information. As such it is imperative to present only the crucial information to the driver, in order to improve the overall situational awareness and decision-making process [8]. The distilling of the information should also be appropriately presented through simplified visual cues that the human eye can follow rapidly and the human brain can interpret in a timely manner.

3. PROTOTYPE HUD

The proposed HUD interface capitalised in an exhaustive trial and error process in order to determine the most acceptable symbols for the visualisation of the potential collision threats in a motorway environment. As such the proposed HUD offered a group of simplified symbols namely; pathway symbol, front vehicle and front vehicle in the same lane symbol, traffic symbol and sharp turn symbol [3,4] as presented in the figure below. The HUD symbols have size-shifting ability following the distance approximation of the obstacles ahead. Furthermore the size alteration of the symbols is accompanied by colour-coded changes, which follow the mandatory regulations of vehicular international standards.

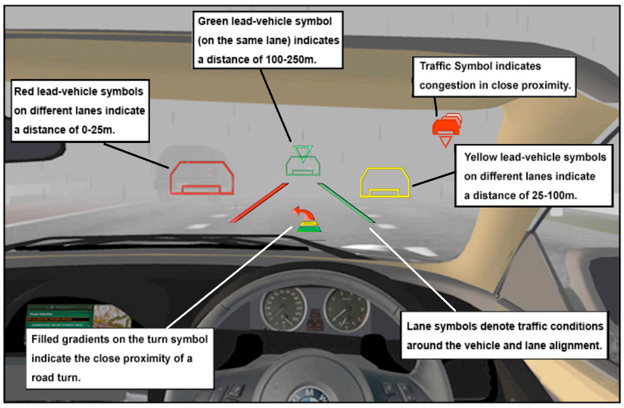

Figure 1: Explanatory HUD interface screenshot

4. EXPERIMENT RATIONALE

The main experiment was based in real-life re-inaction of accident scenarios suggested by local traffic police authorities in UK. Forty licensed drivers participated in these trials varying in age, gender and professions. The primary aim of VRSD was the clarification of the optimal focal depth for the proposed HUD interface. Following the evaluation of the HUD system conducted on the non-immersive OSDS, it was deemed necessary to investigate further the perceptions and ergonomic effects of the projection distance. Due to the prohibitive costs and risks associated with real-vehicle experimentation, it was essential for the study to opt for a VR simulation model. The simulation scenarios tested the users' performance with and without the use of the proposed HUD under low visibility conditions. The response times, and collision avoidance reactions have been recorded with the use of numerical logging of their responses, video recordings and subjective feedback they provided before and after each experiment [3,4,5,9].

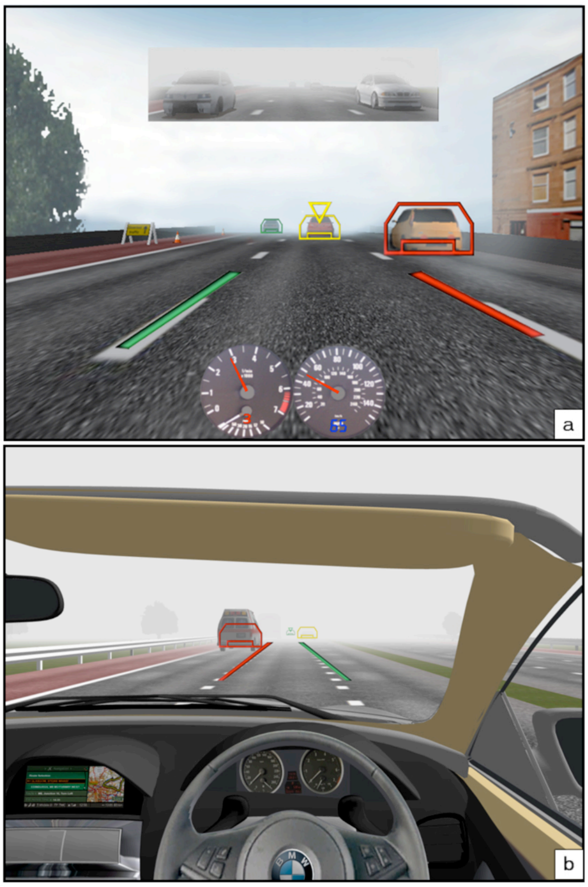

Figure 2: A screenshot of the (a) open source driving simulator and (b) the VR driving simulator

5. DRIVING PATTERNS

With the use of both simulators it was evident that the driving patterns that appeared were consistent irrelevantly of the simulation medium. As such, during the experiments, the users seemed to follow specific reactions, which have been clearly recorded by the aforementioned means of performance monitoring.

In the virtual simulator (VRDS), as in the 2D simulation (OSDS), all users relied on the HUD to identify the surrounding barriers and obstacles in the low visibility scenarios which in both cases produced significantly reduced collisions with rather than without the help of the HUD interface.

The simulation results, particularly from the OSDS, were encouraging as they substantiated the overall HMI design philosophy that was applied to the proposed full-windshield HUD interface. In particular the first simulation provided positive results regarding the interface effectiveness in driving under adverse weather conditions. The interface's acceptability was confirmed by approximately 90% of the users in both simulations (OSDS and VRDS), which indicates an appreciation of the system's contribution in specific conditions [5,6,7].

Evidently the four driving states: low risk, conflict, near crash and crash imminent [10], have been successfully conveyed by the four different colour and shape states of the interface symbols. The headway results presented above have shown that the drivers' spatial and situational awareness have been efficiently enhanced by the interface's visual cues. This quadric segmentation of the headway zones was particularly useful as it highlighted users' driving behaviour, with and without the HUD support. The users struggled to drive through the dense fog and avoid the braking lead vehicles as the test results demonstrated without the use of the HUD. The video recordings clarified that the headway, without the use of HUD, was barely perceived by the drivers, hence a misjudgement of the distance from the lead vehicles consequently resulted in a collision. The HUD interface offered a simple and comprehensible method for aiding users to visually "reconstruct" their diminished perception caused by the near-zero visibility. The geometric (size shifting) and colour (colour coding) attributes of the symbols enabled the drivers to conceptualise the real headway from the lead vehicles.

As a result, the vast majority of the drivers preferred to drive in the "yellow" or "green" level of the colour coding. This enabled them to follow the driving pattern of the lead vehicles, particularly those within the same lane, and respond in an analogous manner to any change in speed or position (lane changes). Therefore 72.5% of the drivers effectively avoided the imminent collision (with the use of HUD) as opposed to 10% who evaded the accident without the HUD assistance.

Another interesting driving pattern appeared in the whole group of forty drivers that participated in the simulation experiments. The substantially different driving styles of younger and older drivers have blurred as both groups were driving confidently yet marginally not exceeding the speed limits even under low visibility conditions, with the use of the HUD interface (REF). In contrary the use of traditional dashboard information agitated the younger drivers, which misjudged the distance from the lead vehicles, resulting in a large number of collisions. Similarly the older drivers performed poorly with the use of the typical Head-Down Display information as their fear of potential collision with the lead vehicles reduced their average speed significantly which either produced collisions with the following vehicles or with even the lead vehicles.

Most users reported a very conscious decision between focusing on either the lead vehicles or the HUD, similar to switching attention between traditional HDD instrumentation and the outside traffic. Given good visibility conditions, the HUD in its current form can distract the driver by introducing visual clutter into the critical field of attention. A revised set of symbols, designed for regular visibility conditions should be considered. This revision should only present information not normally visible through regular perspective; including existing symbols and enhancing their intensiveness (e.g. double lane icons acting as warning indicators for cars in blind spots).

6. CONCLUSIONS

This paper has presented an overview of observed drivers' behaviour patterns in a simple mobility scenario under adverse weather conditions in motorway. The transferability of these results to the overall driving population was presented through the statistical analysis of the OSDS recorded metrics.

Evidently the proposed HUD interface effectively supports a robust and rapid conveyance of information between machine and human. The complementary study on the focal preferences highlighted potential benefits and pitfalls in case of a real-vehicle implementation. Given the imperfections of the simulation systems, it would be ideal to conduct further tests using a physical prototype of the HUD system in a real car to fully validate the results. Notably, bearing in mind the dictum by [11], remarks that the simulators by definition are based in optical illusion to mimic the experience of driving and, thus, it will never become a real vehicle. In our near-future research we aim to develop a real-life version of the proposed HUD.

Notably, in a hypothetical future scenario in which all vehicles are equipped with the specific or similar HUD interface it could be feasible for the drivers to maintain a constant speed and distance (from the lead vehicles) with minor acceptable variations depending the driving styles. The result could be effectively compared with the cyber-cars rationale, which was analysed in the Advanced Driver Assistance Systems (ADAS) current trends in [12].

Yet the fundamental difference would be that the users would still be able to drive their own vehicles, instead of merely reducing them to vehicular robots, and eliminating the joy of driving.

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