Open access • Journal Article • DOI:10.1007/S10111-008-0117-0

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Vassilis Charissis, Stylianos Papanastasiou

Institutions: University of Glasgow

Published on: 01 Mar 2010 - Cognition, Technology & Work (Springer-Verlag)

Topics: Human–machine system, User experience design, Interface (computing), Head-up display and Visibility (geometry)

HUMAN-MACHINE COLLABORATION THROUGH VEHICLE HEAD UP DISPLAY INTERFACE

[1]V. Charissis, [2]S. Papanastasiou, [1]P. Anderson

[1]Digital Design Studio, Glasgow School of Art,
10 Dumbreck road, G41 5BW, Glasgow, UK
v.charissis@gsa.ac.uk, t +44(0)141 3534424, f +44(0)141 3534448

[2]Department of Computing Science, University of Glasgow,
17 Lilybank Gardens, G12 8RZ, Glasgow, UK

Abstract

This paper introduces a novel design for an automotive full-windshield Head-Up Display (HUD) interface which aims to improve the driver's spatial awareness and response times under low visibility conditions. We have further designed and implemented a working prototype of a Human Machine Interface (HMI) to fulfil these requirements. Particular emphasis was placed on the prioritisation and effective presentation of information available through vehicular sensors, which would assist, without distracting, the driver in successfully navigating the vehicle under low visibility conditions. The proposed interface is based on minimalistic visual representations of real objects to offer a new form of interactive guidance for motorway environments. Overall, this paper discusses the design challenges of such a human-machine system, elaborates on the interface design philosophy and presents the outcome of our user trials that contrasted the use of our proposed HUD against a typical Head-Down Display (HDD).

Keywords: HMI, HUD, Navigation, Low visibility, Symbology

1 Introduction

The advent of affordable in-car infotainment equipment and their wide use in several consumer market segments has resulted in growing research interest in in-vehicle Human Machine Interfaces (HMIs). The stimulus overload stemming from the deployment of such devices can, however, distract the driver from the main driving task, which can potentially lead to an accident (Recarte 2003). In recent times and along with traditional instrumentation, the dashboard has been burdened with providing space and mind share for infotainment devices such as GPS navigation and other information facilitators (Kenny et al. 2004). As a result of the prolification of use of this space, Head-Down Display (HDD) interfaces may not effectively provide critical information as the driver's attention may be distributed along several irrelevant information outlets.

A Head-Up Display (HUD) interface inherently increases screen estate for supplementary driving-related information, thus complementing the traditional dashboard, while commanding attention as it lies within the driver's immediate field of view. As a consequence, a simple design may provide further useful information without adding content to the already congested dashboard. By interpreting a wealth of information available through vehicular sensors, a HUD interface could enhance understanding of the vehicle's surrounding space and improve the driver's response times, particularly under low visibility conditions.

This paper elaborates on the design decisions and prototype implementation issues involved in the development of a novel HUD interface and presents the preliminary findings of our initial user trials. Furthermore, our work contrasts the use of the proposed HUD design against a contemporary HDD interface in simulated low visibility conditions. We have engaged observation notes, video-recordings, questionnaires and interviews to gauge drivers' reactions and preferences.

2 Human – Machine Collaboration in Low Visibility

The proposed HUD system becomes a critical regulator of information flow in an imminent crash situation under adverse weather conditions, by facilitating efficient collaboration and interaction between the system (machine) and the driver (human). As the response times involved in avoiding collision in such a scenario are in the order of a few seconds, we assert that an immediate conduit of communication among the vehicle and the driver should precede this event. That link is to be provided by the HUD interface. Note that the reaction responsibility cannot be exclusively delegated either way; recent research has revealed that the decision making process on driving responses should be distributed in a balanced manner among the machine and human elements for all types of vehicle interface design (McCann 2003).

Nevertheless, the human agent can easily experience stimulus and information overload, which may lead to failure of following proper procedures or otherwise cause the agent to perform poorly. Yet, if a machine has been predefined to perform a specific action or calculation, it will consistently execute a set of procedures, in the correct order, substantially minimizing the error possibilities (McCann 2003).

In this study, the machine, with the aid of sensor and radar equipment, is capable of identifying obstacles and inform the driver visually (through the HUD) of the position and speed of leading vehicles; by following a predetermined algorithm the decelerating vehicles can be traced and that information may be passed on to the driver through graphical symbols. Consequently, the system enhances human vision without interfering with the driving process.

3 Interface Design

A major pitfall of HMIs, as applied in vehicles, is the creation of non-intuitive displays. In hazardous situations, such as low visibility navigation in a highway environment, interface delays or provision of irrelevant information due to an ineffective design can be fatal. In our view, interface design and functionality should follow a human-centered approach. Therefore, during the design process of the HUD interface we were particularly interested to amplify and extend the driver's perception and cognitive abilities through visual cues. Subsequently, all the essential information was presented in a graphical form (symbols) that aid rapid processing of the information offered.

Data Representation
Alphanumeric interfaces have been heavily used in the last decades as symbology for real-time navigation. This reflects the original military origins of the HUD design as a means of increasing targeting accuracy of military aircrafts. Despite the fact that these interfaces serve a particular and well defined purpose in that environment, their non-adjusted deployment can be inappropriate in the automotive field. A number of tests showed that HUDs overloaded with information, especially those using textual output, can create the effect known as cognitive capture (Ward 1995).
It could be argued that alphanumeric information can be much more suited in some situations, e.g. defining exactly the vehicle's position in a navigation system. On the other hand, the amount of information that drivers need to process in this manner can substantially delay their reaction to a possible collision incident. Comparative studies of symbols and alphanumeric data in HUDs have conclusively demonstrated that symbols are interpreted much faster by humans (Shekhar et al. 1991).
For reducing or even eliminating visual clutter, the conformal type of symbology for navigation information has been proposed (Fukano et al. 1994). In short, conformal symbology simulates the visual transformations of external objects to give observers the perception that the symbology is part of the external scene (Gish 1995). In this way, it is also feasible to achieve minimal interference between the projected information and the critical details in the actual road scene. Our final design utilises simple geometric shapes as symbols in order to minimize the effect of cognitive capture and issues associated with it. Additionally, the symbols have been colour-coded depending on the vehicle's distance to the object of interest (a road turn or other vehicles for example). Symbol size variability also indicates the speed of the vehicle in relation to the lead vehicles, i.e. indicates the pace of approach. More detailed discussion on this is included in other work (Charissis et al. 2006).

4 Rationale and Experimental Set-up

4.1 Experiment Design Rationale

As an initial design to test-bed experiments, we have considered two commonplace driving situations based on a "car following" scenario. The first scenario, involves 20 vehicles spread across the track, led by a law-abiding, competent driving artificial intelligence. At a predetermined moment the leading vehicles brake instantly, forcing the driver to brake to a halt or proceed to perform an avoidance manoeuvre.
The second scenario recreates a traffic-congestion scene. The "bottleneck" is positioned in a blind turn under a bridge, increasing in that way the accident risk. Both cases were of particular interest to Glasgow Strathclyde Police department as they generate the majority of accidents of car-following collisions (SPD report 2004).
Both scenarios have been tested in a simulated track built to mirror the actual layout of the existing motorway complex between the cities of Glasgow and Edinburgh in the UK. The track as well as the landmarks of this area were modelled using a 3D software package and imported into the simulation engine. The low visibility factor in the experiment was simulated fog which allowed for approximately 5% visibility, as can be seen in Figure 1.

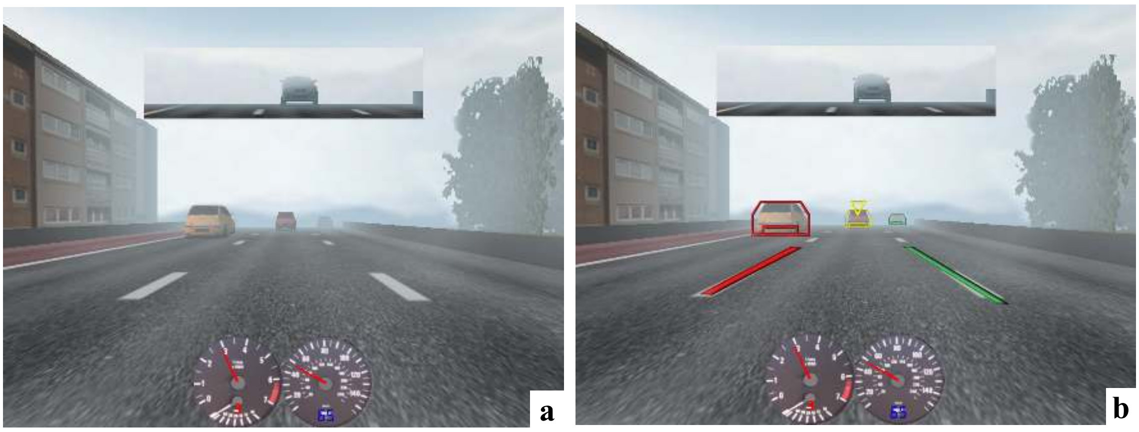


Figure 1. Driving under low visibility conditions
a) With contemporary HDD b) With proposed HUD visual aid

4.2 Driving Simulator

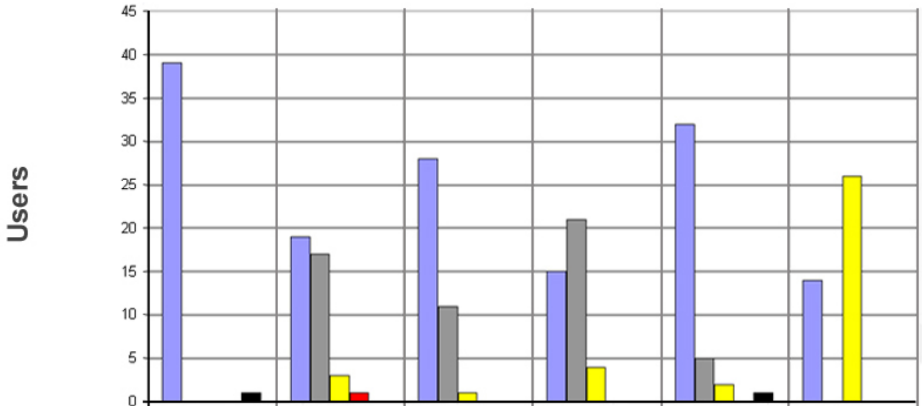
The efficiency of the proposed interface has been tested in simulated low visibility conditions. User trials were carried out with the intent to gauge driver's performance when utilising a HDD, including a functioning tachometer and speedometer (as expected from a contemporary dashboard), against using the simulated full-windshield HUD interface. The tests were accommodated in the E-Motion Lab of Glasgow Caledonian University, facilitated by a number of human reaction measuring devices. The outcomes demonstrate the potential safety benefits of this particular interface.

5 HDD – HUD interface Comparison

The metrics used in our trials were *response time* and *error occurrences*. Data regarding driver's speed, lane position, simulation elapsed time and distance from the leading vehicle were collected every 0.05 seconds. Our preliminary results indicate that the HUD interface can be more efficient than a contemporary HDD both in terms of reducing response times and the number of driver errors. Study of the video-recordings verified these observations. The video footage was captured by two remote-controlled video cameras, whereas one focussed on the simulator's monitor and the other on the driver. The driver's facial expressions and overall posture indicated a heightened level of stress while driving in low visibility conditions especially without the proposed HUD.

The feedback received from post-trial questionnaires and interview responses did not accurately reflect the numeric findings. The relevant questionnaire content as well as the user responses are outlined in Chart 1. In particular, when drivers were asked whether they were driving faster with or without the HUD, 26 of them felt that their speed was the same in both situations. However, analysis of the actual data indicates, that all forty drivers drove faster by an average of 10 to 25 km/h when utilising the HUD. Notably, even though a noteworthy acceleration in the pace of driving had taken place, crashes were considerably less when the HUD had been used (Charissis et al. 2006). It should be further stated that the average speed when using the HUD did not exceeded the highway speed limit**.** Furthermore, 32 drivers experienced fatigue while driving without the HUD under limited visibility conditions and felt it was particularly difficult to keep the car within the lane boundaries. Apart from improving the driver's response times, the HUD also increased confidence and lowered the observed stress level. Again, Chart 1, details the relevant questionnaire results.

Chart 1. Evaluation outcomes of comparison between HUD and HDD.



Questions	Q6	Q7	Q8	Q9	Q10	Q11
Extremely Helpful	39 (Yes)	19	28	15	32	14 (faster)
Very Helpful		17	11	21	5	
Neutral		3	1	4	2	26 (same)
Not Very Helpful		1	0	0	0	
Not Helpful At All	1 (No)	0	0	0	1	0 (slower)

Q6: Would you use this HUD interface navigation system under low visibility conditions?
Q7: How easy was for you to get used to the HUD interface?
Q8: Do you think it would be a helpful system to integrate in future vehicles?
Q9: How helpful was the HUD for decreasing your stress level during driving in low visibility?
Q10: How helpful was the HUD for minimising your stress level compared to the HDD?
Q11: When using the HUD, were you driving faster, the same or slower?

6 Conclusions

We have presented our preliminary evaluation of a proposed HUD design, which aids driver awareness in low visibility conditions. The user trials conducted compared our HUD design with a contemporary HDD interface (dashboard). Our initial results indicate that drivers can navigate effectively, with the assistance of the HUD interface through very demanding accident prone situations even under low visibility conditions. In contrast, the HDD interface was inadequate in supporting the driver with the necessary information required to overcome imminent collision.

Our future research aims are three-fold. First, we aim to examine the behaviour of drivers in scenarios where faulty information is introduced. This should help to simulate more closely real-life conditions. Second, we aspire to redesign some of the existing symbols in accordance to the users' feedback obtained. Finally, we are also working towards realising a fully functional HUD in an actual vehicle, which should allow us to evaluate its performance in a realistic setting. Through this effort it should be possible to closely capture the majority of the perceptual clues available to the driver which may not be adequately represented in our simulation model. Overall, it is our belief that human-machine interaction can be improved substantially in the future if the interface design focuses primarily on human-centered systems, as a means of augmenting human abilities.

7 Acknowledgements

The main financial support for this research project has been provided by the EPSRC (The Engineering and Physical Sciences Research Council) and IKY (National Scholarships Foundation). User trials for this work were carried out in the E-motion Lab, which was graciously donated by the School of Computing and Mathematical Sciences of Glasgow Caledonian University. Finally, we would like to express our gratitude to the Traffic Police Officers of the Strathclyde Police Department for their valuable contribution during the implementation of this research.

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