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Evaluation of Prototype Automotive Head-Up Display Interface: Testing Driver's Focusing Ability through a VR Simulation

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Abstract — **Contemporary automotive, navigation and infotainment requirements have evolved the traditional dashboard into a complex device that can often distract the driver. Head-Up Displays (HUDs) have recently attracted the attention in the field of automotive research, promoting the reduction of driver's reaction time and to improve spatial awareness. The aptitude of the proposed HUD interface lies within the driver's focusing ability to the HUD interface and the actual traffic. This paper analyses the performance behaviour through user-tests using different focal levels for the projection of a full-windshield HUD interface. For this purpose, a VR driving simulator has been developed to test the different depths of field configurations of a HUD while driving in various weather and traffic conditions with and without the HUD. Our simulation results reveal the users' preferences regarding the focal point of the superimposed interface and present a comparative evaluation of the different focal levels and their impact on drivers' behaviour and performance.**

I. Introduction

Advances in automotive electronics and the growth of real-time applications, such as onboard navigation and entertainment systems, have drawn a lot of attention to new ways and interfaces for representing vital information to the driver [1]. Due to limited availability of cabin space particularly in the driver's section, the infotainment devices have burdened the dashboard area, distracting the driver [2, 3]. The windshield utilisation offered a solution by projecting information directly into the driver's field of view. Head-Up Displays (HUDs) exhibit unique characteristics such as unlimited combinations of projected information without any fixed dial's position.

In our research we opted for a full windshield HUD representation as it offers improved response time compared to only partial usage of the provided glass/transparent space [4, 5]. Further experimentation and live trials have demonstrated convincingly that superimposing vital information on a full windshield HUD results in the improvement of the response speed when compared to the response times provided using traditional Head-Down Displays (HDDs) [6, 7]. However, projecting a HUD interface generates a number of implementation issues and Human Machine Interaction (HMI) misinterpretations. The cognitive capture effect that derives primarily from visual clutter of the projected information has been a major problem for the majority of previous HUD attempts [8]. In the proposed interface, simplified visual cues inform the driver of crucial information regarding possible obstacles, traffic situations and road conditions ahead, especially in low visibility scenarios. The second implementation issue is the focal distance of the projected HUD, e.g. the perceived distance at which the symbols are displayed by either projecting directly onto the windshield or using special optics. Previous research with real life experiments has alleged that the ideal distance would be approximately the end of a vehicle's bonnet (1.6m - 2.5m) [9]. Nevertheless, it remained unclear whether the innovative characteristics of the proposed HUD interface would function efficiently in this distance; we therefore developed a VR driving simulator to evaluate the optimal operational distance of the HUD.

The rest of the paper is organised as follows. The next section offers a brief overview of the proposed HMI design for a full-windshield HUD system and outlines its main components (symbolic representations). The succeeding section discusses the simulation requirements for valid depth of field, weather and accident scenario re-inaction for focal distance experimentation. Subsequently, section IV contains a description of the experiment's rationale and a brief description of the methodology for the system evaluation. The final sections present and discuss the results of the investigation. We conclude by outlining the experiment's outcomes and a tentative plan for future work.

II. Head Up Display Interface

The proposed HUD interface has been designed for use under low visibility conditions, such as fog and heavy rain, in motorway environments [10]. The projected graphical symbols have been extensively tested and developed in order to provide the driver with only the vital information for collision avoidance manoeuvring or braking in an imminent collision situation. Thus, considering the nature and the format of the information (real size vehicles, buildings and other obstacles), it deemed more suitable to use a full scale design for increasing driver's spatial awareness. Furthermore, for enhancing human senses - vision in particular - the symbols appear with colourful visual cues adhering to the SAE colour coding standards. Additionally, they alter their dimensions following perceptively and proportionally the object that they represent.

During the development of the HUD display, four pieces of information were primarily identified as the most crucial for collision avoidance on motorways. This information was visualised through iconic representation of actual objects producing four symbols, namely lane/pathway recognition, lead vehicle detection, traffic warning and sharp turn notification (the symbols are presented in Figure 1). A brief description of the proposed HUD symbols system is provided further on.

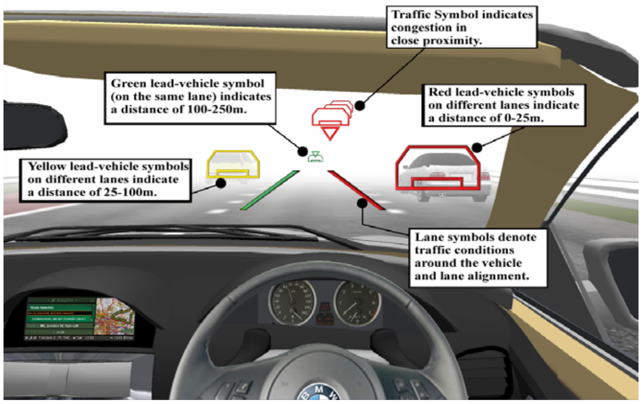

Figure 1 HUD Design

A. Lane Symbol/Pathway: The pathway display concept was originally designed and developed for aviation HUDs [11, 12]. Our symbol is a simplified version, redesigned and adjusted for automotive use. It appears as a composition of converging lines that are superimposed on the real road lane markings. Due to this real life image replication, the driver is constantly informed about the vehicle's position on the road and eventually prevents him/her from an accidental lane departure.

Colour coding of the lane strip provides an obstacle warning. A red lane strip indicates an object on the side of the vehicle, either another vehicle or the lane barriers, whereas green indicates an unobstructed lane.

B. Lead Vehicles Symbols: This category of symbols is used for indicating leading vehicles, thus acting as a rear collision warning system. This function was considered essential for enhancing the driver's spatial and situational awareness and, in particular, for indicating the distance to the front vehicle.

The lead vehicle travelling in the same lane has been highlighted by an inverted triangle added on the top of the symbol, as depicted in Figure 1, to further improve situational awareness. To avoid confusion through visual clutter, only the first row of leading vehicles has been superimposed by the interface. The symbols "follow" the vehicles proportionally and entail four colour states denoting distance/risk levels: blue → green → yellow → red. Furthermore, the relative position of the lead vehicle symbols and the lane/pathway symbols improve driver's spatial awareness significantly and further affirm the quality of the information [13].

C. Turn Symbols: This navigation function relies on GPS and road mapping software, providing information for early identification and warning of motorway sections with limited visibility such as junctions, intersections and hairpin turns, which can be particularly tricky to traverse. The arrow points into the direction of the upcoming road turn, indicating the distance by colour coded stripes. It initially appears in light blue and distinct stripes of green, yellow and red are added depending on the distance from the potentially hazardous road turn. This function has no relevance for the user tests presented here and has not been implemented at this stage.

D. Traffic Symbol: The rapid deceleration of the leading vehicles approaching a traffic bottle neck is a typical accident scenario on motorways [14]. The traffic symbol denoting congestion is a HUD feature that appears gradually, indicating the position and distance of the formed traffic congestion. A warning for the abrupt deceleration of a leading vehicle due to traffic congestion greatly reduces the risk of rear collisions. Additionally, a traffic notification symbol can be useful when the obstructing traffic situation is hidden from the driver's field of view (i.e. around corners, under bridges, low visibility conditions).

An in-depth analysis of the symbols' design and functionality in the HUD interface has been provided in [15, 10].

III. Simulation Requirements

To test the impact of variable focal distance of HUD symbols, an immersive virtual reality driving simulation was developed. The system had to provide a reasonably convincing driving experience and replicate the effects of different HUD configurations. In particular, it had to provide an accurate sensory stimulus for different depth of focus configurations.

A. Driving Simulator System

The simulator used to test the HUD is an extended version of the VR simulation system as introduced in [16]. It was originally developed to assess calibration requirements and extended for this evaluation towards an interactive driving simulation and instrumented with status logging and scenario management.

1) Software

The driving simulator software is built using the Multigen VEGA Prime virtual reality development toolkit. VEGA Prime provides the simulation framework and real-time graphics and audio rendering support, including stereoscopic rendering to provide the impression of depth. VEGA Prime also provides simulation of atmospheric effects, including time of day, clouds, fog, rain, and snow. The software simulates driving on a straight motorway with moderate traffic.

The driving simulation implements a simple driving model providing realistic acceleration, deceleration and drag dependent on speed. It does not simulate any further effects such as skidding or a response to crashes. We found that such a simple model was sufficient for the given test scenarios (as discussed in section IV).

The other cars on the motorway are implemented as autonomous agents with basic collision avoidance and overtaking logic. They try to achieve their individual target speed and switch lanes if a car in front is slower, while avoiding collisions at the same time by adjusting their speed and avoiding blocked lanes. Their target speed varies between 25m/s and 40m/s.

2) HUD Simulation

The HUD simulation uses textures with a transparency channel that are rendered as billboards on the position that is defined by the intersection of the ray from the driver's head to the respective car and a virtual plane (HUD plane) that is parallel to the windshield (see Figure 2). The chosen distances of 0.7m, 2.5m and 5m were suggested by the literature as the main focusing distances investigated in previous HUD projection research [17, 18, 19]. The position (distance to driver) of the HUD plane depends on the test scenario and defines the focal distance and hence the stereo disparity at which the symbol is rendered.

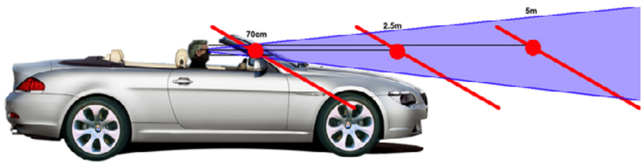

Figure 2. Side view of driver and car to illustrate the position and distances of the HUD plane.

3) Hardware

The user sits comfortably in a driver's seat that has a steering wheel with force feedback and foot pedals for accelerator and brake attached (see Figure 3). The car interior and the environment are displayed on a 1.8m wide by 1.2m tall back-projected screen using an active stereo CRT projector. The screen is positioned 1.3m away from the user. The user wears wireless stereo goggles that separate the images for the left/right eye respectively. All software runs on a single PC with two Intel Xeon 3.6GHz processors and a high-end graphics card (nVidia Quadro FX4400). The system maintains a steady frame rate between 40 and 60Hz, providing a smooth experience.

IV. Experiment Rationale

The identification of the optimal focal depth of the HUD interface was the primary aim of this experiment. During the first phase of the evaluation of the proposed HUD design [13] on a non-immersive driving simulator it became clear that, although the HUD was performing well, we had to further investigate the perception and ergonomic effects of projection distance to validate the previous results. Due to the prohibitive costs and risks associated with experimenting in real cars, we opted to implement a simulation system using virtual reality technology first.

Previously, our hypothesis was that the HUD interface would be helpful only under low visibility conditions, typically less than 50m. It was unclear, though, how users would react to the additional information projected on the windshield in a good visibility situation, and therefore, whether the design was transferable beyond its original design specifications.

To test the hypothesis, a number of test scenarios were defined (section IV.B) and tested using the virtual reality car simulator system as introduced in section III. All scenarios include driving on a straight motorway, avoiding other traffic. A traffic jam occurred at a defined distance. Once the driver reached the obstacle (or crashed into it), the scenario was ended and the operator switched to the next scenario as soon as the test subject was ready.

Figure 3. User on the simulator.

A. Stereoscopic Rendering for Depth of Field Simulation

Stereoscopic rendering as used in VR projection environments simulates accurately the disparity of an object as perceived due to different perspective caused by the distance between the eyes (inter-ocular distance). The other two major components of human depth perception and distance estimation, motion parallax and eye focusing, are ignored in our tests. There is only minor motion parallax due to physical head motion in a driving situation due to restricted movement in the seated position. The lack of effective depth-of-field simulation using traditional projection technology, however, will influence the test results to a certain degree and ultimately require a final validation using a real car. When driving, the vast majority of people effortlessly refocus between distant objects (e.g. other cars) and the car's instrumentation; hence we assume that our simulation results are reasonably transferable.

B. Evaluation Scenarios

A set of eight test scenarios was designed to evaluate the effectiveness and ergonomics of the HUD under various visibility conditions and focal distances (see Table 1). The test operator manually selects the scenario and instructs the user to start driving.

Scenarios 1 to 3 were designed to replicate and validate previous results obtained through a 2D simulation [13] that simulated driving in extremely low visibility. They also test whether the user notices a difference between different focal distances under low visibility. They test the hypothesis that the different focal distance between the HUD and the cars would not cause difficulties under very low visibility conditions.

Table 1. Test scenarios.

Test	Daytime	Visibility	HUD	Comment
0	Noon	inf.	off	Familiarization
1	Noon	40m	off	
2	Noon	40m	0.7m	
3	Night	40m, rain	2.5m	
4	Dawn	inf.	off	snow
5	Dawn	inf.	0.7m	
6	Dawn	inf.	2.5m	
7	Dawn	inf.	5m	
8	Noon	30m, snow	2.5m	rain

Scenarios 4 to 7 test whether the HUD design would be effective under good visibility, even though it was originally designed for low-visibility situations exclusively. They challenge the hypothesis that a large difference in focal distance between the HUD interface and its corresponding real object might confuse the driver.

Scenario 8 simulates a very low-visibility situation again to validate scenarios 1 to 3 by examining learning or familiarisation effects.

All scenarios include the simulation of a traffic jam after a varying distance, between 1500m and 4000m after the start of the scenario. The introduction of this obstacle enabled us to check the effectiveness of the traffic warning symbol.

Scenario 0 was defined to let the user to familiarise with the simulator and its controls. The test operator would only start the following scenarios after the user felt comfortable driving the simulator. Furthermore, each scenario and their sequence during the experiments were explicitly designed to avoid drivers recognising test patterns. Additionally the weather conditions (visibility limits) and variety of HUD projection distances enhanced the feeling of running completely different simulations. Thus it was feasible to minimize the influence of subjects' learning curve on the test results.

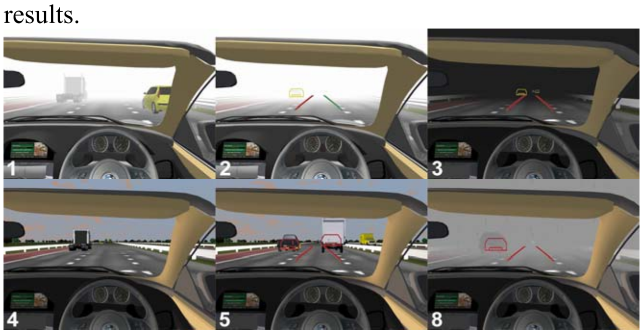

Figure 4. Screenshots of different scenarios.

C. Evaluation Data

The evaluation of the system was based on three different types of data sources. The test subjects were asked to fill in a pre- and post-test questionnaire. The questionnaires were designed to provide consistency with earlier test series [13, 12]; yet new questions dealing explicitly with focal distance and simulator sickness issues have been added. During the test, the operator motivated the test subjects to report general impressions and asked specific questions relating to effects and preference of different focal distances (e.g. "Do you notice a difference in the HUD compared to the previous scenario?", "Do you focus on the car's dashboard or on the HUD?", etc.).
Due to the number and range of simulation scenarios it was essential for the study to derive verbally as much information as possible from the drivers regarding every individual scenario. This was deemed necessary as after the completion of the experiment the user would possibly not express or recall the initial thoughts he/she had about the different aspects of every simulation. However the experimenter was encouraging in a timely manner this expression through a "co-driver chat" without diverting the driver's attention.

Finally, the simulator software created a log file for every test subject. This log included information about the running status (current time, position, speed, acceleration) and individual events (start of scenario, hard braking, crash).

D. Test Subjects

The results presented in this paper are based on 12 user tests, which is the suggested average number for such experimentations as shown in previous studies [17, 18, 19]. All test subjects were either university students or staff with various educational and cultural backgrounds, 7 female and 5 male, aged between 25 and 57. One test had to be aborted due to acute simulator sickness.

V. Evaluation Results

The test results were analysed based on three data sources: The pre- and post-test questionnaire, logged status data and the comments of the test subjects.

A. Analysis of Questionnaire

The post-test questionnaire mostly confirmed the oral comments the test subjects provided during the test. The vast majority preferred using the HUD in bad weather, whereas a majority considered it to be too distracting to use in good weather. They generally preferred the longer focal distances (see Table 2 and Figure 5).

Table 2. Selected Questions in the Post-Test Questionnaire

Questions	
Q06	Would you use this HUD interface in navigation system under bad weather conditions? Yes / No
Q09	Would you use this HUD interface in in good visibility as in situations %, 6 and 7? Yes / No
Q10	Which distance of the HUD projection would you prefer? A) 0.7m B) 2.5m C) 5m
Q11	If you were using in good visibility any of the symbols, which one would you prefer to have in your HUD? A) lane/pathway symbols B) vehicle identification symbols C) traffic identification symbol

As an interesting anomaly that will require further investigation, a majority of test subjects thought they were driving faster with the head-up display, when, in fact, their speed was almost constant regardless of the HUD configuration (see section V.B).

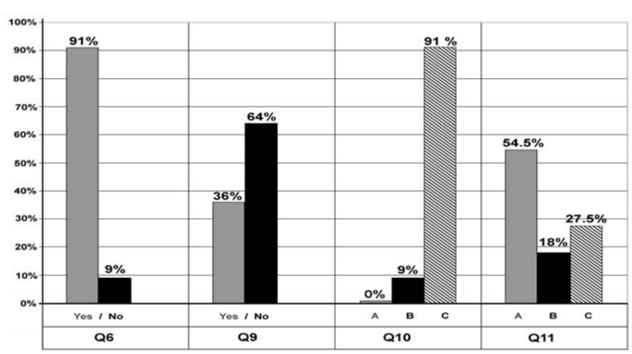

Figure 5: Graphical representation of the questionnaire results.

The questionnaires covered other areas, such as a task load evaluation and driver's background information, forming a total of eleven questions (post questionnaire). However the aforementioned questions were of particular interest to this study. The other results were consistent with data from previous tests [10, 13] and are not discussed further in this paper.

B. Analysis of Log Data

The analysis of the logged data provides some insight into the driver's behaviour. The average driving speed and maximum speed was extracted from the logged data.

The maximum speed provides an insight into how comfortable the users felt given the weather conditions. It is largely independent from factors that varied between tests and subjects such as other traffic. The maximum speed also clearly reveals whether a test subject treated the test as a video game.

While the maximum speed varied significantly between the test subjects (the standard deviation ranged from 5.2 and 7.9 m/s between scenarios), the averaged max speed of all subjects was surprisingly constant across scenarios, with approximately 30m/s for all scenarios with low visibility (1-3, 8) and approximately 35m/s for those scenarios with good visibility (4-7). The focal distance setting of the HUD had no significant influence on the driving speed. It did have a significant impact on the probability of accidents, though, with most drivers crashing into the traffic jam in scenario 1. Generally, drivers became more careful (slower) towards the end of the test series, but all clearly exceeded what would be considered a safe speed given the extremely low visibility.

The analysis of the average speed per scenario revealed the same trends as the maximum speed analysis. The measurements, however, include a larger error margin, caused by test subjects not immediately accelerating after the scenario was started and due to the significantly different duration of the scenarios, influencing the impact of the initial acceleration phase (the car stood still at the beginning of each test).

C. Impact of HUD Focal Distance

The different configurations of the HUD distance had no measurable impact on average or maximum driving speed. The test subjects, however, reported very consistently on the subjective impressions during driving.

In low visibility scenarios, all users relied on the HUD to identify other cars. A majority of users focused on the road marks for lane keeping, however. Between scenarios 2, 3 and 8, most users commented on the lack of contrast between the yellow and green icons against the grey background (fog during daytime), but only noticed the different focal distance after being asked explicitly. No test subject commented negatively on the short focal distance in scenario 2. This supports the original design hypothesis that given very low visibility, short distance focusing of the HUD will not distract the driver as it becomes the primary orientation source with few outside visual cues available.

Focal distance, however, did become an issue in scenarios 5-7. All users reported immediate discomfort in scenario 5, with difficulties focusing on either the car in the distance or the respective HUD symbols on the windscreen at a focal distance of only 0.7m. All users preferred driving without a HUD under good visibility. Changing the HUD focal distance to 2.5m as in scenario 6 was considered a very significant improvement by all but one (see section VI.A) test subjects, although users still reported some distraction due to the depth mismatch of the symbols and the car. Switching to 5m focal distance in scenario 7 was considered a further improvement by most, although about half of the users reported a minor difference only.

It can be concluded that users generally preferred a longer focal distance to reduce refocusing strain on the eyes. However, this was less pronounced under the very low visibility condition where test subjects relied exclusively on the HUD, which is in line with the original design intention [13].

Most users reported a very conscious decision between focusing on either the outside car 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).

VI. DISCUSSION

The analysis of the test results confirms the original hypotheses. Particularly the effects of focal distance under low visibility conditions are encouraging that the original design will work in practise. As expected, the results indicate that the HUD design needs further optimisations to reduce visual clutter and distraction in high-visibility conditions.

A. Statistical Relevance and Consistency of Data

The test results were based on 12 test subjects. One set of data was incomplete due to motion sickness; two other sets were of reduced relevance due to either excessive speeding (participant treated the trials as a game) or overly cautious driving. Combined with a degree of randomness in the simulation of the other cars, the measurements of speed, reaction times and number of crashes involve too much variation to make final judgments regarding the effectiveness of the HUD. Nevertheless, our main interest for this series of tests was on the ergonomic aspects of different focusing distances. The effectiveness of the HUD interface to convey vital information under low visibility conditions has been tested and validated in previous research already [10, 13].

The qualitative interview comments were consistent. All test subjects preferred similar HUD focal configurations and experienced the similar focusing difficulties. There was only a single subject who did not notice significant differences between different HUD focusing distances. On closer examination, it was found that this person generally had severely limited stereoscopic vision due to squint, which fully explains the different test result.

B. Simulation Side Effects

Several test subjects mentioned minor effects of simulator sickness. These are caused by conflicting sensory information to the brain, mostly due to the absence of acceleration forces and the incomplete depth information, limited resolution and slight blurriness by the stereoscopic projection system used. As the VR driving simulator is under development, user's feedback on the quality of the simulation has provided the research team with valuable information and suggestions for further improvements. The amount of simulator sickness caused by these experiments is typical for this type of virtual reality simulation in our experience.

C. Transferability of Results to Real World

Given the imperfections of the simulation system, particularly the inability to simulate depth-of-field effects using current VR projection technology, it is clear that further tests using a physical prototype of the HUD system in a real car will be required to fully validate the results. Nonetheless, we feel confident that the issues identified through the simulation will remain valid.

VII. Conclusions

This paper presented an enquiry into the suitability of three HUD interface projection distances (0.7m, 2.5m and 5m). Through eight simulation scenarios based on an actual, live trial occurrence, we have demonstrated that the most preferred and comfortable projection was the furthest one (5m in-front), offering more consistent alignment with the existing physical objects between the eyes. Furthermore, we identified and analysed the connection between maximum speeds achieved and the focusing ability of the driver.

However, the experiment has highlighted some potential problems stemming from the non-real but virtual representation of the depth of field through the VR driving simulator, which could be dealt with by developing further the hardware and software capabilities of the system by utilising users' feedback from the current experiment. In the future we aim to measure driver's performance in a number of new collision scenarios provided by Strathclyde Police Department of Glasgow, UK. Finally, we are also in the process of verifying our simulation results in more demanding driving scenarios and environments and finally validate our conclusions in a real life HUD interface prototype mounted on an actual vehicle.

References

[1] D. D. Salvucci, "Predicting the Effects on In-Car Interface Use on Driver Performance: An Integrated Model Approach", International Journal of Human-Computer Studies, 55(1), pp. 85-107, 2001.

[2] R. Phaal, "Foresight Vehicle Technology Roadmap: Technology and Research Directions for Future Road Vehicles", UK Department of Trade and Industry, 2002.

[3] J.D. Lee, J.D. Hoffman and E. Hayes, " Collision Warning Design to Mitigate Driver Distraction" *In Proc. CHI 2004*, ACM, 2004.

[4] Steinfeld, A. and Green, P. (1995). Driver Response Times to Full-Windshield, Head- Up Displays for Navigation and Vision Enhancement, Technical report, Transport Research Institute, University of Michigan, U.S.A.

[5] R. Kiefer, and A. Gellatly, "Quantifying the Consequences of the "Eyes-on-Road" Benefit Attributed to Head-Up Displays" (SAE Paper 960946), Warrendale, PA: Society of Automotive Engineers, 1996.

[6] H. Yoo, O. Tsimhoni, H. Watanabe, P. Green, and R. Shah, "Display of HUD Warnings to Drivers: Determining an Optimal Location" (Technical Report UMTRI-99-9), Ann Arbor, MI: The University of Michigan Transportation Research Institute, 1999.

[7] J. W. Horrey, C. D. Wickens and A. L. Alexander, "The effects of Head-Up Display Clutter and In-Vehicle Display Separation on Concurrent Driving Performance", Proc. of the 47th annual meeting of the Human Factors and Ergonomics Society 2003.

[8] N. J., Ward, A. M. Parkes, "The Effect of Automotive Head-Up Display on Attention to Critical Events in Traffic", *International conference on Experimental Analysis and Measurement of Situation Awareness*, Daytona Beach, Florida,1995

[9] K. W. Gish, and L. Staplin, "Human Factors Aspects of Using Head-Up Displays in Automobiles: A review of the Literature", Washington, DC: National Highway Traffic Safety Administration (report no: DOT HS 808 320), 1995.

[10] V. Charissis, S. Papanastasiou, "Design and Evaluation of an Automotive Full-Windshield Head-Up Display interface: Low visibility guidance and navigation", Proc. of the 6th International Conference in Visualisation, Imaging and Image Processing, VIIP'06, Palma de Mallorca, Spain, 2006.

[11] M. P. Snow, J. M. Reising, K. K. Liggett and T. P. Barry, "Flying Complex Approaches Using a Head-Up Display: Effects of Visibility and Display Type" International Journal of Aviation Psychology, Vol. 11, No. 1, Pages 33-51, 1999.

[12] G. Billingsley, J. K. Kuchar and S.W. Jacobson, "Head-Up Display Symbology for Ground Collision Avoidance", International Journal of Aviation Psychology, Vol. 11, No. 1, Pages 33-51, 2001.

[13] V.Charissis, S.Arafat, W.Chan and C.Christomanos, "Driving Simulator for Head Up Display Evaluation: Driver's Response Time on Accident Simulation Cases", Proc. of the Driving Simulation Conference DSC'06, Asia/Pacific, Tsukuba/Tokyo, Japan, 2006.

[14] C.F. Daganzo, "A Behavioural Theory of Multi-Lane Traffic Flow. Part I: Long Homogeneous Freeway Sections", Research Report ucb-its-rr-99-5, Institute of Transportation Studies, University of California at Berkley, U.S. , 1999.

[15] V. Charissis, S. Papanastasiou, "Exploring the Ad Hoc Network Requirements of an Automotive Head-Up Display Interface", Proc. of the 5th International Symposium on Communication Systems, Networks and Digital Signal Processing, CSNDSP'06, Patras, Greece, 2006.

[16] V. Charissis, M. Naef, M. Patera, "Calibration requirements of an automotive HUD Interface using a Virtual Environment: Methodology and Implementation", in Proc. Of the International Conference in Graphics and Visualisation in Engineering, GVE'07, Clearwater, Florida, US, 2007

[17] M. Sakata, S. Okabayashi, J. Fukano, S. Hirose, and M. Ozone, "Contribution of head-up displays (HUDs) to safe driving", in Proceedings of the Eleventh International Technical Conference on Experimental Safety Vehicles. NHTSA, Washington, D.C., US, 1987.

[18] R. Kiefer, Effect of a head-up versus head-down digital speedometer on visual sampling behavior and speed control performance during daytime automobile driving, SAE Technical Report Paper No. 910111, Society of Automotive Engineers New York, US, 1991.

[19] S. Okabayashi, M. Sakata, and T. Hatada, "Driver's ability to recognize objects in the forward view with superimposition of head-up display images, In Proceedings of the Society of Information Displays, pp 465-468, 1991