11AE-0113

On the Impact of Early Warning Collision Avoidance Information through Prototype Head-Up Display for Older Drivers

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ABSTRACT

Human cognitive and physiological performance tends to enfeeble during time. Evidently a distinct attenuation of reaction-times spatial and situational awareness appears in the older segments of the driving population which increases rapidly in the western civilisation. Additionally, greater dependence on private automotive transportation and the unremitting raise of the elderly population, contributes to a significant increase of collision occurrences. To this end we have designed a prototype Head-Up-Display (HUD) interface which offers crucial information to the driver, in a timely manner. The interface comprises symbolic representation of the lead vehicles and road information acting as a vision enhancement system. The evaluation of the system contrasted the proposed HUD interface to the existing Head-Down Displays (HDD) offering encouraging results, with significantly decrease collision occurrences tested different accident scenarios. Our future tentative plan of work encompasses a highly customisable interface symbols and calibration which will encounter visual impairments of each driver.

INTRODUCTION

Technological advances have enabled numerous collision-avoidance systems to be gradually incorporated into contemporary vehicles through the form of visual, auditory and haptic interfaces. Although these systems aim to provide the driver with early warning avoidance information it is evident that their interfaces might obscure the driving performance of elder users (Inzuka et al., 1991). This particular group suffers more than anyone else from slow response times, due to age-related deterioration of their senses and reflexes. Furthermore the rapidly increasing aged-population of the western hemisphere stipulates an urgent solution to the collision avoidance of this significant segment of the drivers. In addition to the aforesaid issues, adverse weather conditions and unexpected traffic congestion can diminish elder drivers' reaction times, increasing significantly the collision occurrences and fatalities.

Mindful of the aforementioned observations, we have developed a full windshield Head-Up Display (HUD) interface in order to provide the driver with crucial collision avoidance information. In particular this paper presents the design process for the prototype HUD interface, which aims to improve the driver's spatial awareness and response times under low visibility conditions. Through an incremental process of interface design and functionality improvements we aimed to enhance the response times, particularly of the elder drivers through a number of additional visual inputs. Evidently our previous research with respect to HUD systems has indicated that such interfaces may enhance significantly the driver's spatial and situational awareness resulting in faster responses and successful collision avoidance (Charissis et. al., 2008, 2010). For faster correlation of the real environment information and the provided information, the latter is superimposed in the windshield through symbolic representation of the forthcoming obstacles and vehicles by masking and highlighting the real-time visually obscured cues.

In order to evaluate the effectiveness of the proposed system, our driving simulator was customised to accommodate the superimposed information of a full-windshield Head-Up Display (HUD) interface for the elder drivers' in low visibility and traffic congestion driving scenarios (Lee et a., 2003). The evaluation of the proposed HUD focused mainly in the driver's performance, measuring the actual response times (RT) and headway (HW) benefits derived through its usage and subsequently the real impact in the decrease of accident propensity.

Overall the paper discusses in detail the interface design mantra and presents the results of a comparative evaluation of the HUD system versus the typical dashboard (HDD) information. Furthermore this work presents an exhaustive analysis of users' age, gender, collision occurrences and the collision speed (m/sec) of each user, which can offer an informative appraisal of the effectiveness of the HUD system through the estimation of collisions per trial, with and without the HUD interface. The preliminary trial results are particularly encouraging, yet they produced a number of intriguing users' feedback which we aim to incorporate in the next version of the prototype HUD.

ELDER DRIVER HAZARDS

Older drivers represent a rapidly growing segment of the drivers' population. However the produced vehicle interior systems offer a wealth of information and entertainment devices which hampering drivers' attention. Previous studies demonstrated that the cognitive capabilities and senses diminish in geometric progression to the age (Rasomething 2010). As such the over elaborate or over-simplified in some rare cases, design of in-vehicle interfaces do not take into consideration the physical and cognitive limitations that older drivers present. In particular the navigation systems present various road information that this group of drivers cannot interpret or use in a timely manner.

The direct impact of these coexisting issues is often an erratic driving pattern and consequently results on collisions. Current research efforts have concentrated on the ergonomics and interface development in order to assist the elderly. Yet the produced systems so far resolve partially the problem. The main hindrance appears due to the fact that the development groups do not comprehend or recognize the level of customization and simplification which should applied in order to improve older drivers' road safety {REF].

Another interesting aspect is the findings of psychological and qualitative studies with regard to how the older drivers perceive and evaluate their daily driving performance (Charles 2010). Interestingly the older drivers perceive themselves as more experienced road users in comparison to the younger drivers, yet they feel that they require significantly more time to read, comprehend and respond to the in-vehicle and environment information. In addition reduced stamina, increased glare sensitivity and inability to compute all the incoming information render them incapable to react on time in a fast developing situation which requires instant decision making and response.

HUD INTERFACE

Concurrent studies have repeatedly highlighted that car-navigation systems should preferably placed near or at the center of the field of view in order to minimize the eye movements and reaction time of the older drivers [itoh]. To this end we designed and implemented a prototype guidance/navigation system which is projected on the driver's direct field of view through the use of a Head-Up Display (HUD) system. Aware of the eye accommodation issues that this positioning might generate, we utilized the full-windshield in order to immerse the projected information to the external environment. As such the crucial collision-avoidance information typically concerning the lead vehicles are concentrated in the middle as shown in the Figure 1.

This information entails the following. A *pathway symbol* which presents the lane borders and alters colour depending the sensing of vehicles on each side, providing a clear warning for the blind spots. The *lead vehicles'* symbols are designed to highlight the first row of leading vehicles. The vehicle in the same lane with the user is additionally noted with an inverted triangle. Also a *traffic symbol* appears in the top of the windshield spotting the potential flow bottleneck. The interface concludes with the *turn symbol* which acts as an early warning for sharp and potentially unnoticeable road curves that might prove difficult to negotiate.

Overall we aimed to design and implement the functionality of a small number of attention-seeking symbols which would "follow" the real-time traffic and highlight the potential collision points with the use of colour coded and shape-shifting representations. The primary challenge was to provide auxiliary information to the driver without diverting significant mind-share from the primary task. To this point it was deemed essential for the success of the interface to avoid creating visual cueing effects so subtle that would go unnoticed by the driver. To avoid such an eventuality, the appearance of each symbol is accompanied by an auxiliary consideration:

the relatively sharp transition in colour states drawing inspiration from the concept of an "abrupt stimulus onset" as described in (Wickens & Hollands, 2000). Specifically, as the sudden induction of any element to the driver's field of view can cause unexpected reactions, the symbols were arranged to appear through a sequence of gradual (but distinct) changes with regard to their colour-changing pattern (Carlsson, 2003). Generally, the symbols used in this design appear in light blue and then change to green, yellow and finally red as the events they refer to come closer to the user's vehicle.

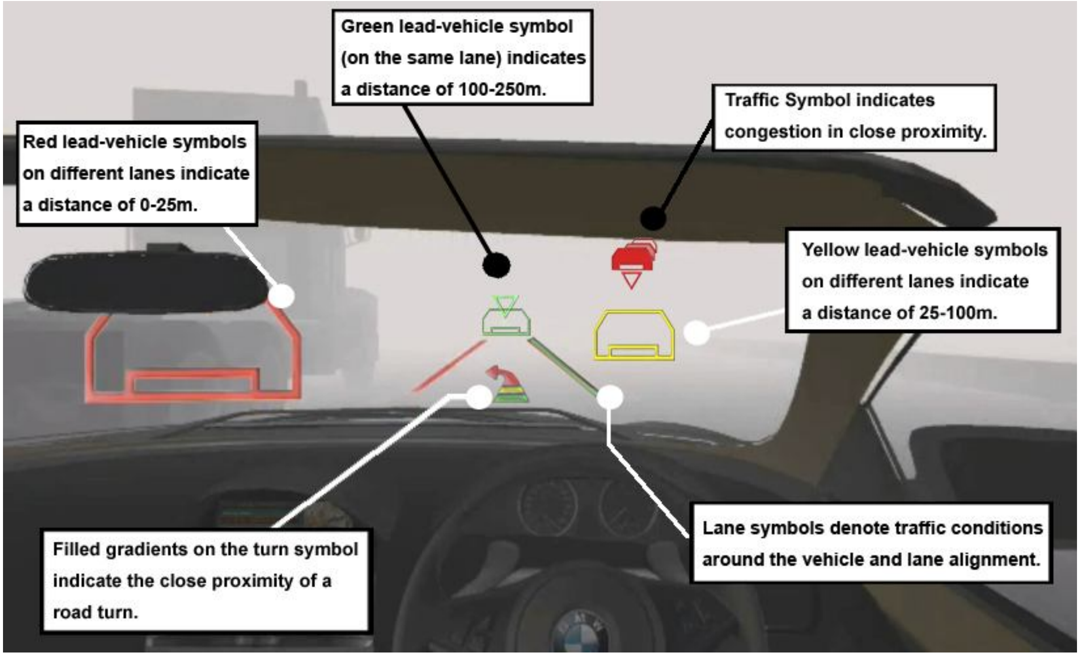


Figure 1–Screenshot of the actual Driving and brief HUD interface explanatory information.

MODELLING AND SIMULATION

To prove or discharge the effectiveness of the proposed interface an evaluation tool was required. This simulation necessity led to the development of a custom driving-simulator (OSDS) based on open source code and off-the-shelf hardware components [DS]. The positive impetus of the simulation results offered a clear understanding of the potential and drawbacks of such interface. The nascent field of artificial intelligence in the automotive field was employed in order to increase the realism of agent vehicles involved in the simulation scenarios [AI]. Their characteristics were derived from everyday life examples and driver behaviours described in the related literature and real-life accident scenarios provided by Strathclyde Police Department in Glasgow.

The main simulation scenario re-enacted a typical rear-collision accident using a generic car-following model [4]. This scenario has been used previously on our work during the development and evaluation of different modules and aspects of the prototype HUD system [REEEEEF]. This scenario challenges the reflexes and decision making of the driver which drives in a motorway stretch between Glasgow and Edinburgh. The external environment is hazy due to simulated dense fog which creates zero visibility conditions. The incident occurs after few minutes of uneventful driving in the aforementioned conditions, when the lead vehicles brake abruptly due to a collision in between them. As may be anticipated, this scenario increases considerably the probability of rear vehicle collision. This probability reflects the risk involved in the different stages of response performance that an average driver might have and can be mapped in of four distinct driving states: low risk, conflict, near crash and crash imminent [5]. As such, the first scenario was developed along these guidelines in order to evaluate the HUD's ability to convey effectively these four collision states to the driver. Segmenting driver's performance-map into these four pre-collision periods provided the study with advantage of being able to identify the impact of the HUD information as compared to a typical HDD. These four periods have been translated through colour coding and shape sizes in the symbols used for the proposed HUD interface.

Forty users with valid driving licence and aging between 20 and 75 have been selected to participate in the evaluation process. Also for validation purposes, the vehicles flow and road information has been programmed to follow the British Highway Code. From simulation point of view we opted for a photo-realistic representation of vehicles as depicted in figure 2.

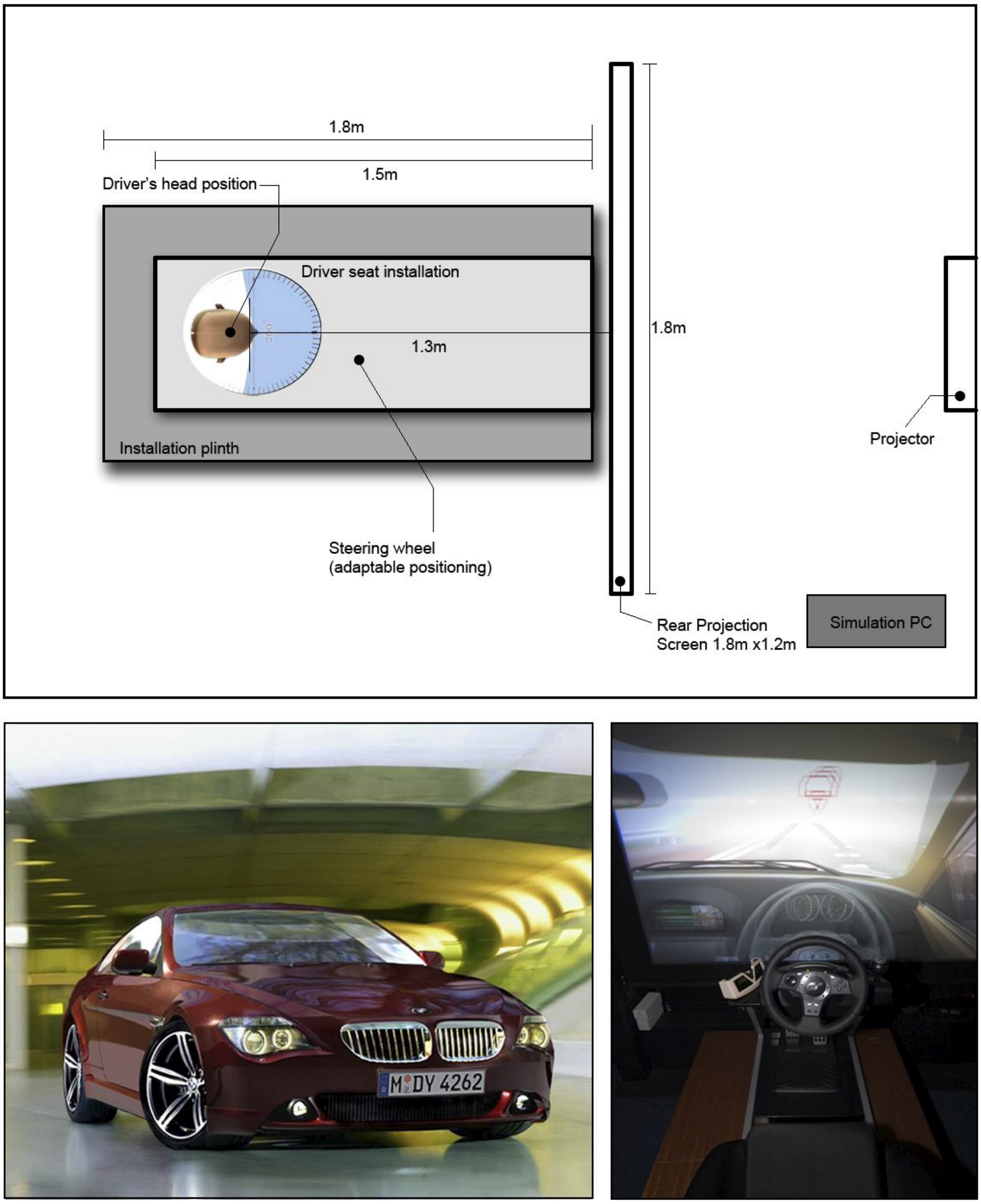


Figure 2 –Virtual Reality Driving Simulator set-up including stereo projection for immersive driving experience.

SIMULATION RESULTS

An analysis of the results had shown a minor correlation between the age of the users and their driving performance with regards to the collision occurrences. However it is evident that the use of the HUD had improved their driving reactions as four out of eight (50%) did not collide with the front vehicle during the abrupt braking scenario. Furthermore the remaining four drivers that collided while using the HUD assistance they have performed considerably lower impact collisions as they managed to brake, reducing the collision speed. Notably all the older users collided with full speed (no breaking reaction) with the use of HDD.

Notably one of the users was removed due to exceptionally slow driving that was considerably outside the experiment design objectives (user 23). For the data analysis it was employed a binary logistic regression technique with collisions as dependent variable and age as independent. This statistical analysis was applied in the results of both cases (i.e. with HUD and with HDD), which are presented below.

Collision Occurrences vs. Age with HUD

The derived data have been analysed with multiple in order to identify the correlation of the HUD interface and the drivers' age into their collision avoidance performance. For the analysis we used Cox & Snell R Square and Nagelkerke R Square which provided results of 11.7% and 16.9% respectively. The model summary indicated that the relationship between age and collision is not negligible due to the high rates of both the R-squares, considering that the age factor is one of many that affect driving performance. Therefore 16.9% for one factor is not negligible.

Performing an analysis of variance presented the aforementioned significance is confirmed; as the B-coefficient for Age is 0.049, indicating that the age affects driving performance. Consequently older drivers have significantly increased probability to collide with statistical significance at the 3.7% level.

Collision Occurrences vs. Age with HDD

The following group of tables present the statistical analysis of the collision results with the use of the traditional instrumentation panel, (HDD). As expected, the ANOVA of the HDD results demonstrates that B-coefficient for Age = .011 suggests that someone older has a higher chance of colliding. However, it is not statistically significant (sig=77.9%). This occurs due to the small sample of users that might be sufficient for the HUD evaluation, but due to the extensive collision rates of the vast majority of the drivers is not ideal to identify a relationship between age and collision occurrences. This is clearly presented in the following Table 1. Evidently, there is not much variability in the age variable though, 53% are aged from 20 to 35; in addition to the fact that almost 90% of the drivers crashed in the simulated scenario without the use of HUD.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	20-35 years	21	53.8	56.8	56.8
	36-50	9	23.1	24.3	81.1
	51-80	7	17.9	18.9	100.0
	Total	37	94.9	100.0	
Missing	System	2	5.1		
Total		39	100.0		

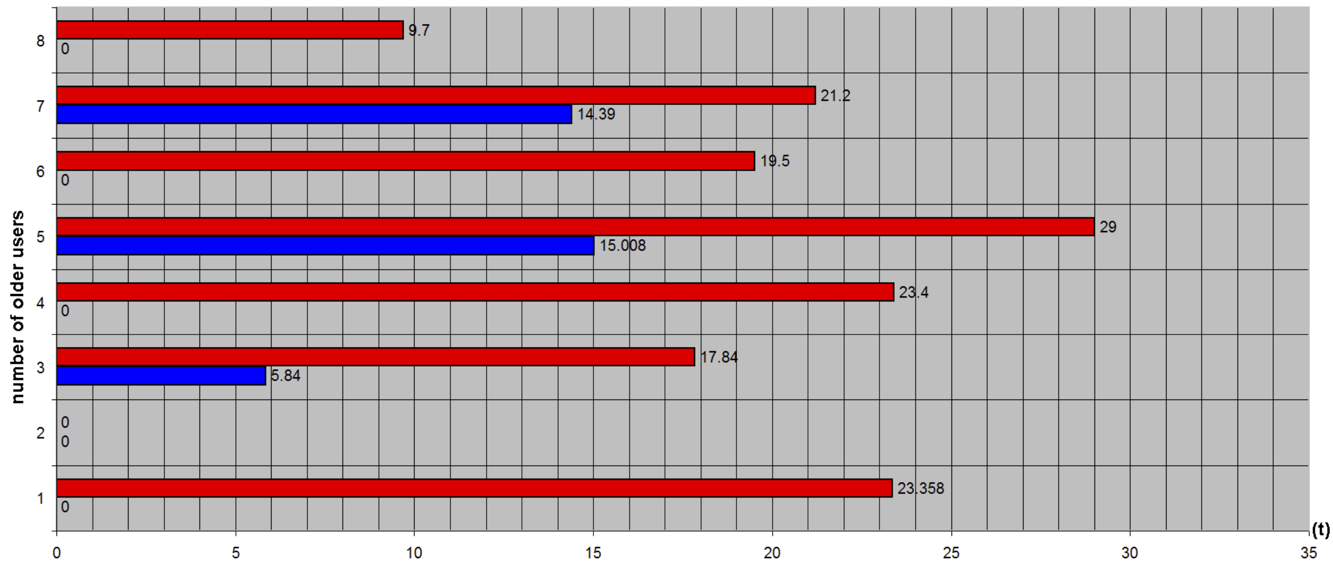
Table 1: Age Groups

The analysis of the collision occurrences has demonstrated that the age could affect driver's performance with HUD. Although this does not imply that older drivers' performance had deteriorated. In contrary a succinct investigation of the collision occurrences and the collision speeds demonstrates a significant improvement in collision avoidance as 50% avoided the collision in comparison to the results derived from the HDD as Chart B above illustrates.

DISCUSSION

It is noteworthy that the majority of the elder users identified almost instantly the symbols' functionalities without the need of the typically lengthy manual instructions, which is a standard for the majority of navigation systems and other infotainment devices. One immediate ramification of the design mantra employed in the proposed HUD interface, was the significantly decreased collision occurrences. This was predominantly an achievement of the simplicity of the interface that conveyed clearly and in timely manner the essential information. Furthermore the selection of a full-windshield projection enabled the driver to correlate the highlighted symbols with the actual scenery. Concentrated research towards this projection method is currently being undertaken by automotive manufacturers, as the small estate HUDs do not easily blend with the external environment. Hence the user has to "translate" the miniscule projected data to the actual road, which takes away the driver's attention from the actual road.

The older users in particular presented a significant improvement on their response times when using the HUD system which reflected on the decreased collisions or low-impact collisions in comparison to their performance with the use of the typical dashboard information. It is worthwhile to highlight that one older user in the rear-collision accident scenario, did not manoeuvre and collided with 23m/sec which will potentially have been proved a fatal collision in real-life. In contrary the same user managed to avoid completely the abruptly braking lead vehicles, decelerate in a calm fashion and stop safely behind the accident. During the qualitative analysis and post-trial interview the user suggested that he felt calmer and relaxed about the front and side traffic as all the potential collision hazards were presented to him well in advance. This observation was made by all the forty drivers that participated in the trial. As such the system managed to achieve a result of maintaining the driver calm; hence empowering him/her to proceed in a thoughtful decision making that was not previously considered feasible. In this way the older drivers that could not rely on the instinctive and rapid responses, could utilise their experience given the fact that the system was maximising their available time-to-collision (TTC) window.



	1	2	3	4	5	6	7	8
HDD	23.358	0	17.84	23.4	29	19.5	21.2	9.7
HUD	0	0	5.84	0	15.008	0	14.39	0

Fig. 3: Comparison of collision speeds (a) with HUD and (b) with HDD

Nevertheless three older drivers failed to avoid collision even with the use of the HUD system, yet their collisions were a result of very slow response times which could not be anticipated in the first place. Interestingly these drivers collided with significantly less speed when using the HUD system than without as presented in the Figure 3. Analysing further the video-footage and the correlated measurable information of lane-changing patterns, braking, response times, and acceleration patterns we are currently developing an additional interface tool which we envisage that will eliminate or minimise even further these potential collisions.

CONCLUSIONS

This paper investigated the typical concerns appearing on the older drivers' population and presented a prototype HUD interface which counteracts significantly the aforementioned issues. The proposed system presented fresh opportunities for the portrayal of information using symbolic representation on a larger viewing area than was previously possible, as the system utilizes the full-windshield. The positioning and presentation of crucial information through the HUD presented a particularly suitable medium to convey such information as, in contrast to HDD instrumentation, may situate visual cues in close proximity to the driver's road-seeking gaze. Maintaining a subtle and non-distracting visual representation there is little need for the driver to divert attention away from the driving task. The consequent evaluation and comparative study between the two systems offered encouraging results in favour of the proposed HUD system. The latter demonstrated significant improvement on the response times and collision avoidance when used by older drivers. Additionally the simplistic presentation of the essential collision avoidance warnings was perceived rapidly by the older users proving the effectiveness of the minimal style of the interface. Towards these suggestions the paper finally outlines a future plan for an increasingly customisable system, which will incorporate a direct manipulation interface for easier customisation and personalisation of the symbolic representations.

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