On the Impact of User's Computer Knowledge on Driving Simulation Test Results - HUD Simulation Case Study

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Abstract

Contemporary studies have focused on the development of rear collision avoidance or warning systems, in order to assist drivers during demanding driving situations and weather conditions. However, vehicle's controllability through human decision-making is often impaired due to unambiguous interface designs. Our effort focuses on the development of a system that could complement human senses instead of replacing them, and improve users' response times under adverse weather and traffic conditions. To this end we developed a prototype Head-Up Display (HUD) interface that could effectively convey the crucial information in a timely manner. The system's effectiveness was validated using a custom simulation system and evaluated through trials with 40 users. In this paper we will present a succinct overview of the HUD system and we will investigate the correlation of users' driving performance and their computer knowledge. The potential impact of computer familiarisation and simulation results will be analysed explicitly through the collision occurrence results derived from the comparative study of the HUD against the contemporary instrumentation panel.

1 Introduction

Driving simulators have become increasingly important in view of their promise to investigate safely and in a controllable environment a variety of different driving scenarios. Hence, numerous aspects that affect human behaviour during unexpected driving events could be investigated effectively. By isolating and executing predetermined scenarios, the simulation software can test and reveal users' reactions to a given situation. Without tight control of the experiment, the number of probable reactions to a complicated real scenario could generate various "reaction-paths" which could multiply so rapidly that it would be impossible to predict and analyse all the branching possibilities individually. Through selecting the most prominent branch, we can investigate efficiently particular aspects that could affect human reactions to potentially hazardous driving situations. To this end the simulation tasks are designed to elicit and challenge these behaviours, with the final objective to measure driver's performance (Allen et. al., 2004).

Mindful of the aforementioned observations, a driving simulator was developed to investigate the efficiency of a full-windshield Head-Up Display (HUD) interface. 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).

However the computer generated (CG) environment of our simulator resembles similar computer game simulators. Subsequently, it has remained an open research question whether these similarities could affect the results derived from those users who are familiar with such computer games or from users which are generally familiarised to operate personal computers. In an attempt to counteract the familiarisation level with the computer games, the computer-manipulated vehicles were infused with artificial intelligence that allowed them a more random style of driving, imitating everyday commuting traffic flow (Charissis et. al., 2007).

A thorough investigation into the correlation between the performance results and the users' familiarisation level with (a) computers and (b) computer games has provided the study with intriguing results that are analysed in this paper in two sections corresponding to the above categories. The rest of the paper is organised as follows: The next section offers a brief overview of the HUD interface design components. The following section will elaborate on the accident simulation. The simulation requirements will be presented in section 4 and the subsequent section 5 will contain a detailed illustration of the simulation results regarding the headway time differences between HUD and HDD, with emphasis to the drivers' performance with regard to their computer knowledge and their computer-games familiarisation. A discussion will follow which elaborates the impact of the HUD system and the potential issues that might arise in a physical prototype implementation. Finally we will outline the proposed system issues and potential outcomes and present a tentative plan for future work.

2 Head-Up Display Overview

Head-Up Display systems have predominantly been investigated as a faster and more efficient way of presenting information to the aircraft pilots, as opposed to the typical instrumentation panel (Watler & Logan, 1981). Almost forty years later this technology has infused into the automotive industry. Recent developments in vehicular manufacturing have rendered HUD interfaces as an increasingly viable alternative to traditional Head-Down Displays (HDD) (Karvonen et. al., 2006). These interfaces present fresh opportunities for the portrayal of information using symbolic/alphanumeric representation and feature a larger viewing area than was previously possible.

Due to the unique positioning of HUDs inside a vehicle (windscreen projection), it is phenomenologically plausible to present any type of information directly within the driver's field of view. In particular, HUDs can offer a large screen estate that could be populated with different types of information. Evidently, the flexibility provided by these interfaces with respect to the type of information projected is well beyond the bounds set by HDDs, partly due to the larger screen estate of HUDs and due to the nature of presentation (superimposed to the actual objects). Looking for an ideal use of the display, Strathclyde Police Department in Glasgow, Scotland, suggested that the most prominent and fatal accident situations occur under very low visibility in a motorway environment (Ward et al., 1994). Hence a guidance human-machine interface (HMI) would ideally be developed for and tested in such conditions. Following their suggestion, we designed the proposed HUD interface for use under low visibility conditions, such as fog and heavy rain (SPD, 2004).

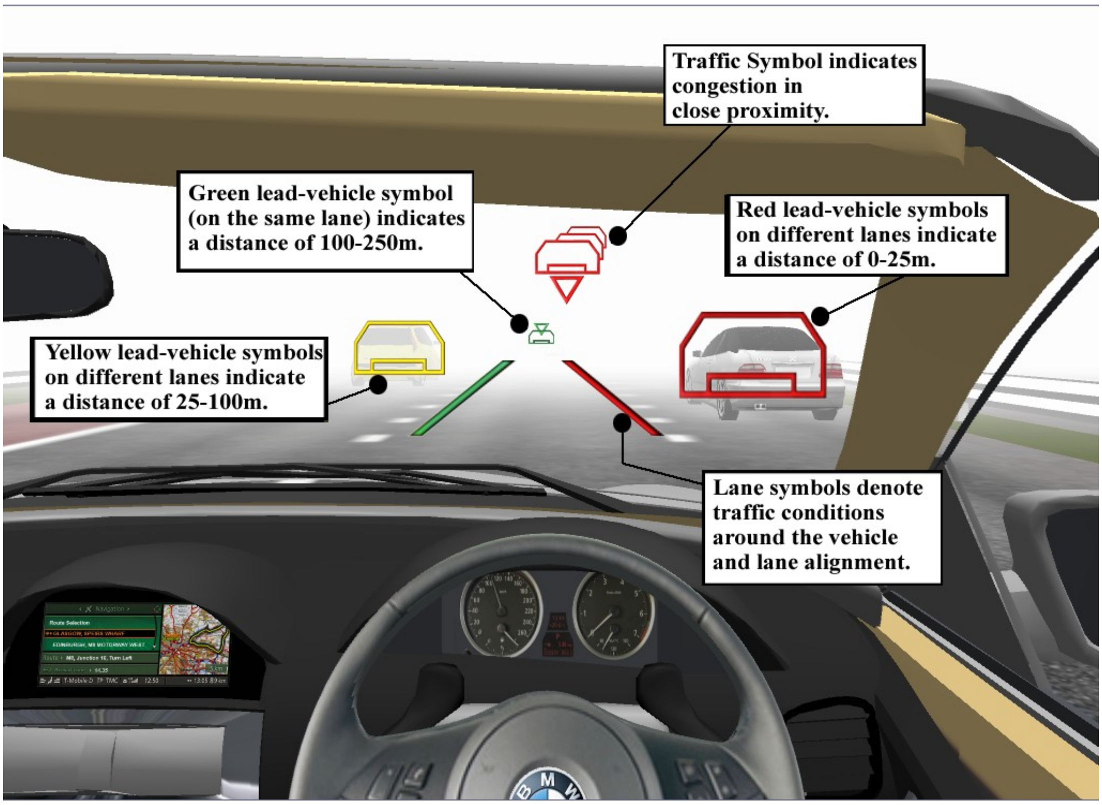

Figure 1: The HUD elements as presented during simulation

Typically a major issue in the readability and accumulation of information through dashboard devices is heavily related to the alphanumeric method of presentation. Conformal or symbolic representations could offer considerably faster response times instead (Charissis & Anderson, 2006). Comparative studies of symbols and alphanumeric data in HUDs have conclusively demonstrated that symbols are interpreted much faster by humans (Fukano et. al., 1994).

The proposed HUD interface design offers a range of symbolic representations with a two-fold functionality: visual warnings and visual enhancement. Considering human attention limitations and performance anxiety levels in a driving situation under low visibility on a motorway, it was evident that the system should convey crucial information only.

The development process of the HUD display highlighted four types of information that were identified as the most crucial for collision avoidance in motorways. This information was visualised through symbolic representation of actual objects, producing four symbols, including lane/pathway recognition, lead vehicle detection, traffic warning and sharp turn notification. The HMI symbols are described briefly in Figure 1.

3 Simulation

The HUD interface under investigation was incorporated into the synthetic environment of a driving simulator. However, recent research work has shown that driving simulators developed for testing purposes cannot be generic in nature; they should instead be optimised to fit the objective of the evaluation (Yoshimoto and Suetomi, 2006). As such, the actual simulation system was based upon an existing driving simulator that was used to provide a reasonably convincing driving experience and extended to replicate the effects of different HUD configurations (Charissis et. al., 2006).

The simulated accident scenario used in this work is a variation of a generic car-following model (Brackstone et al. 2003). In particular, the user is driving along the motorway and after having travelled a distance of 2km, the lead vehicles have been scheduled to brake abruptly, causing approaching vehicles to decelerate rapidly. As anticipated, this event increases substantially the chances of vehicle collision. Furthermore the simulation environment includes heavy fog with very low visibility (visibility < 50m). For validation purposes, the movement, speed and distances of the vehicles have been programmed to follow the British Highway Code.

The results presented in this paper are based on 40 user tests. All 40 test subjects held a valid driving licence and they were aged between 20 and 75.

4 Evaluation Results

The sample set was based on forty test subjects whose performance was measured as collision occurrences within a specified test scenario. The data analysis has presented an informative appraisal of the effectiveness of the HUD system through the estimation of collisions per trial, with and without the HUD interface (13). However, this paper seeks to identify the correlation between the computer knowledge and computer games familiarisation of the driver and his/her collision avoidance dexterity. The analysis of the results includes the significance of these factors and their impact on users' performance. Supplementary subjective feedback from post-test interviews further informs the potential repercussions of these factors. Notably one of the users was removed from the original data set, due to exceptionally slow driving that was considerably outside the experiment design objectives.

4.1 Collisions vs. Computer Game Familiarisation - with HUD and with HDD

We employed a binary logistic regression with collisions as dependent variable and computer games familiarisation as independent. This statistical analysis was applied in the results of both cases (i.e. with HUD and with HDD), which are presented below. The tables below offer a trail of the analysis methods that were utilised in order to identify the correlation of the HUD interface and the drivers' aforementioned attributes into their collision avoidance performance.

Table 1. Model Summary for HUD (Collision vs. Game) .

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	45.338(a)	.027	.039

The HUD model summary (Table 1) above indicates that the relationship between *computer-game familiarisation* and *collision* occurrences is *negligible* due to the diminutive rates of both the R-squares. Interestingly (Table 2), B-coefficient for Games = 0.437 shows that the less is somebody playing, the more chances he/she has to collide. However this result is *not statistically significant*.

Table 2. Variables in the Equation for HUD (Collision vs. Game) .

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1(a)	games	.437	.454	.925	1	.336	1.548
	Constant	-2.776	1.986	1.954	1	.162	.062

Similarly the HDD model summary (Table 3) above illustrates that the relationship between computer-games and collision is minuscule and effectively negligible due to the very low rates of both the R-squares. Interestingly the numeric data did not offer a clear view of any correlation of the above factors.

Table 3. Model Summary for HDD (Collision vs. Game) .

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	19.646(a)	.038	.091

In accordance with the above results, Table 4 depicts that the B-coefficient for game related performance shown the less somebody plays, the less chances to collide, but not statistically significant (sig = 30.7%).

Table 4. Variables in the Equation for HDD (Collision vs. Game) .

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1(a)	games	-1.151	1.128	1.042	1	.307	.316
	Constant	7.586	5.269	2.073	1	.150	1970.648

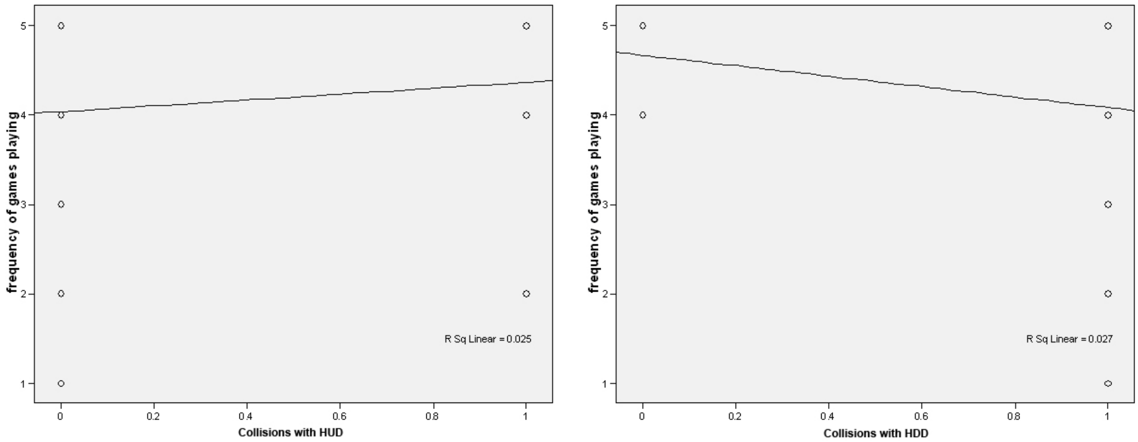

Figure 2: Comparison of computer games familiarisation vs. collision graphs (a) with HUD and (b) with HDD

4.2 Collisions vs. Computer Knowledge - with HUD and with HDD

Analysis of the collision occurrences has demonstrated that the computer knowledge does not affect driver's performance with or without HUD. This derives from an extensive investigation of the data which present that the vast majority (92.5 %) of the drivers use in daily bases a computer for various purposes. Hence an average proficiency in typical applications is assumed. Apparently this variable does not relate to collisions, as almost the whole users' sample fall into the same category.

However a closer examination suggests that the computer knowledge variable could be related with the amount of expertise in computing. Specifically 25% of the users were in some respect associated to computing science. Evidently, these drivers had better performance as they were potentially used to computer-generated graphics, and had a degree of anticipation. Still the users' sample did not allow a clear demonstration of this correlation between variables. Hence it is our intention to repeat the experimentation with a considerably larger and more diverse sample and with the main objective to investigate this correlation in particular.

A cross-investigation of the aforementioned results and previous analysis of the simulation annoyance levels presented in the Charissis et al., 2006 also highlights a relation between users' performance and simulation. Elaborating to this end, the drivers non-professionally related to computers found more difficult to familiarise themselves with the simulator than users with a computer science background. As we anticipated such segmentation of the users' sample, we invested a significant amount of effort for the development of realistic AI for each simulated vehicle as described in (Charissis et al. 2007). Due to this prior intervention, the advantage of the "computer scientists" group was not fully revealed as the vast majority of the users (92%) collided in the simulation without the HUD assistance. However, this group familiarised faster with the simulation environment and the simulation hardware.

Notably the older users exhibited the slowest familiarisation pace. This also vaguely affected their performance. Evidently, the aforementioned performance observations correspond directly to their computer knowledge, which was probably inadequate to provide them with familiarisation with the simulation hardware and software. The comparison of these two highly diverse groups - computer scientist and older users - suggests a relation between a driver's performance in a simulated environment and his/her computer knowledge. However, a larger test sample size might clear the mist of these intriguing but not fully conclusive results.

5 Conclusions

This paper presented the findings between the drivers' reaction and their level of computer knowledge as well as their familiarisation with the game driving simulators.

The evaluation addressed the effectiveness of a proposed HUD design that supports driver awareness while driving under low visibility in a motorway environment. To facilitate an appraisal of the system, 40 users were tested in order to compare the drivers' performance with and without the use of the proposed HUD interface. This study focused particularly on the driving performance related to computer knowledge and computer games familiarisation of the users and the potential impact of these users' attributes in the simulation results.

The experiments have shown that the computer knowledge might have an insignificant impact to driver's reaction. However older drivers clearly felt more uncomfortable in the simulation environment than the younger users. Furthermore the computer-games related comparison between users illustrated a more game-play perception of the simulation by the younger drivers.

Drawing from these results, our future work seeks to entertain the possibility of expanding the simulators' recordings in order to identify automatically the degree of interference that the computer familiarisation can have in CG driver simulators' user-tests. Furthermore we aspire to repeat the simulation with considerably larger number of users so as to identify any potential changes to the aforementioned results.

6 References

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