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Published in:
Proceedings of the International Display Workshops

DOI:
10.36463/idw.2022.1004

Publication date:
2022

Document Version
Author accepted manuscript

How Users Experience Autonomous Vehicle Driving: Provision of Information Through AR HUD

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Keywords: Autonomous Vehicles, Augmented Reality, Head-Up Display, User Experience, Human-Computer Interaction.

ABSTRACT
This work examines if the provision of information through Augmented Reality (AR) Head-Up Display (HUD) alleviates passengers' anxiety during autonomous vehicle (AV) driving. The evaluation was performed in a VR driving simulator, by ten volunteer users. The preliminary results present the benefits and drawbacks experienced by the users.

1 Introduction

Traffic flow is a vital element of daily commuting and travelling by car. Typically fluctuations in the volume of vehicles in a given segment of the road and their average speed could create traffic congestion.

A similar effect could be the output of various weather conditions that result in a decreased average speed of the volume of the vehicles. Road conditions, road works and other infrastructure issues could create or increase additional traffic congestion issues. As such, maintaining an average speed for all the vehicles involved in each segment of the road could potentially reduce traffic flow fluctuations. The above could have significant benefits on the environment, and commuting time [1].

The automatic adjustment of speed, starting and stopping of the flow simultaneously by all the neighbouring vehicles, however, could only be achieved through autonomous vehicles (AV) which will use a combination of technologies related to sensors, Vehicular Adhoc Networks systems (VANETS) and machine learning (ML) amongst other [1-3]. However, AV level 4 where the vehicle can operate in fully autonomous mode deprives the driver of any possible interaction with the driving process [4]. As this emerging technology is unfamiliar territory for typical drivers, it creates evident anxiety regarding the readiness level of the vehicle to manoeuvre effectively through complex daily driving scenarios [4-6].

This work explores the impact of autonomous vehicles and their implications for user experience. In addition, the paper investigates the use of HUDs to alleviate the users' anxiety by presenting the follow-up manoeuvres of the AV in contrast to the existing process in which the user/driver is unaware of the vehicle's short-term plan of action. The latter has been highlighted as a major anxiety issue for AV driving of level 4 autonomous capabilities [6].

To alleviate or reduce this issue and provide a level of preparation for the driver and the passengers before any manoeuvres are performed by the AV, we opted for the provision of Augmented Reality visualisation through a full-windshield Head-Up Display (HUD) [7,8]. Previous studies related to HUD interfaces have shown that improved human performance and reduced driver anxiety were achieved for different driving scenarios and conditions [9-12]. Overall this work presents the interface design (ID) and user experience (UX) feedback from the ten volunteer users' that experienced and evaluated the near-collision driving scenarios with and without the use of the HUD in a fully AV immersive VR simulation. In conclusion, the paper discusses the outcomes of this preliminary evaluation and offers recommendations for the development of comparable interfaces that could further alleviate the driver's anxiety within fully autonomous driving vehicles.

2 Project Rationale

To identify the effectiveness of the information provided through the proposed HUD interface in contrast to the absence of any information provided, we have developed an evaluation process to identify users' experiences and preferences. The evaluation scenario involved a near collision event and last-moment manoeuvring response from the AV. This event occurred seamlessly in two different simulations with and without the provision of information through the prototype HUD. The evaluation of emerging technologies software and hardware could be a challenging task in real-life scenarios. Therefore the simulation of systems and activities that could compromise safety in real life should be tested in virtual environments. The latter has been applied in different fields such as medicine, engineering and built environment [14-17].

2.1 Software and Hardware Requirements

A. Software

The evaluations were performed on our in-house VR driving simulator. The simulator is built upon the Unity3D game engine offering flexibility in the 3D visualisation and relevant coding libraries.

The simulator presents a large section of motorways that connect Glasgow to Edinburgh and Stirling, cities in Scotland. The overall length of the road is 28 miles. The motorway is simplified intentionally to a homogenous three-lane plus hard shoulder lane road. The simulation entails different weather options, lighting conditions and terrains. The 3D visualisation of this track also accommodates the main landmarks and vegetation alongside the route aiming to immerse further the local driver participants. The simulation software is also coupled with a recording application that records several variables such as vehicle speed, position on the road, distance from neighbouring vehicles, braking and acceleration.

B. Hardware

The simulator's hardware is installed in the Virtual Reality Driving Simulator (VRDS) laboratory. The simulation vehicle is a real-life car (Mercedes A Class 2003) situated in the middle of a CAVE (Cave Automatic Virtual Environment) room as depicted in the simulator schematic in Figure 1.

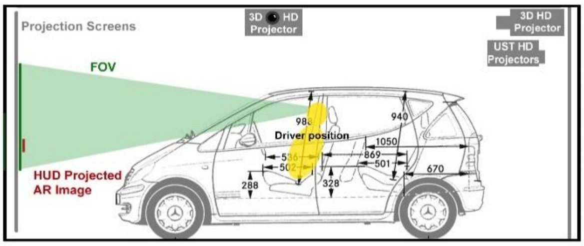

Fig. 1 VRDS Laboratory Set-Up

The CAVE supports surrounding projections that immerse fully the driver. Furthermore, the system immersion benefits from a 5.1 surround audio system and an in-vehicle vibration system for enhancing the realism of the simulated environment.

2.2 HUD Systems for Evaluation

The HUD interface developed for this experiment was based on previous studies developed to support driver decision-making and reduce response times (RTs) in an imminent collision situation. Specific symbolic representations and positioning of the interface, produced a hybrid version of the User Interface (UI) as can be seen in Figure 3. However, the particular UI had only one task – to present to the driver the manoeuvring process that the AV was about to execute. As such the UI symbols followed a minimalistic design and familiar colour coding [18-21]. This manoeuvre was presented in a form of one to two steps with colour-coded arrows and the estimated speed required to complete the collision avoidance task as shown in Figure 2.

2.3 Participants

Ten users participated in this preliminary study who held valid UK driving licences and were aged between 20 and 65 years old. The 10 users were 5 female and 5 male, coming from different social and professional backgrounds.

Fig. 2 The Autonomous vehicle (AV) provides visual information through the AR HUD preparing the driver for any collision avoidance manoeuvres [22].

2.4 Evaluation Process

The user evaluation was performed in three stages. In the first stage, the user completed a pre-questionnaire which collected primarily demographic information.

In the second stage of the experiment, the users experienced a fully autonomous driving simulation which challenged the AV system to circumvent a potential collision in a high-speed motorway environment. This simulation was performed twice; once with and once without the provision of the imminent manoeuvring process of the HUD system. The simulations' lasted for 10 minutes each and they were randomly selected for each user. The duration of each simulation was approximately 10 minutes. The third stage of the experiment required the user to complete a post-questionnaire and provide their subjective feedback regarding the efficiency of the HUD to reduce their anxiety.

3 Evaluation Results & Discussion

The results acquired from the evaluation process received from the users on the post questionnaire highlighted some interesting points, concerns and expectations. . A five-scale Likert system was utilised to measure the users' responses. The post-questionnaire statements are presented in Table 1 below.

Table 1. Post-Questionnaire Characteristics

Q1.	I felt comfortable/safe with the AV driving without any information provided.
Q2.	I felt comfortable with the AV driving with HUD information provision.
Q3.	The HUD interface was simple and informative.
Q4.	The HUD interface needs more information.
Q5.	The HUD interface was using familiar symbols.
Q6.	The HUD was offering a relaxing experience.
Q7.	The HUD information was stressful.
Q8.	I would prefer audio instructions as well.
Q9.	HUD is reducing my anxiety during AV driving.
Q10.	I trust the AV manoeuvring process.

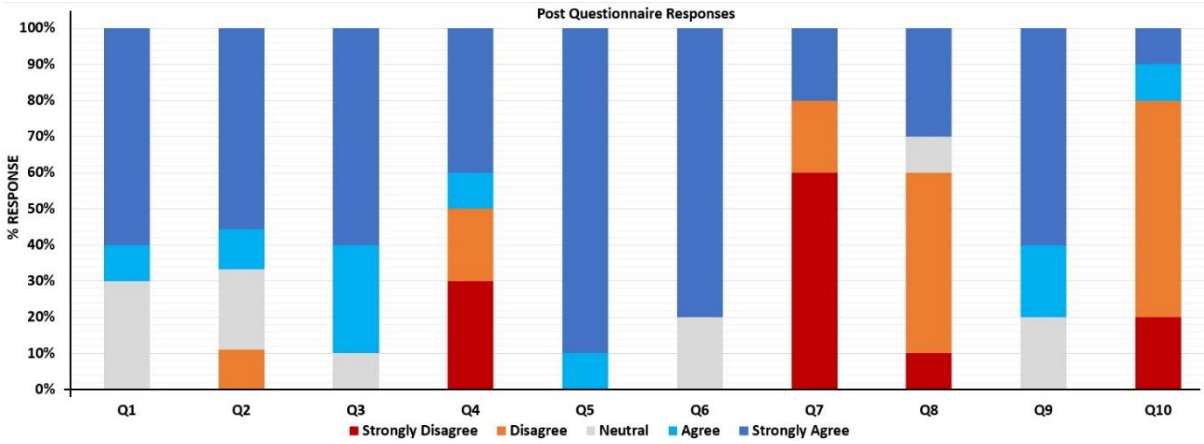

Fig 3. Post Questionnaire Responses - AV and UX1

In particular, 70% of the users responded in Q1 that they were not feeling comfortable/safe when the AV was driving without any input from them, as illustrated in Figure 3. The Q2 presented encouraging results as 60% of the users responded that the HUD provision of information was comforting, as it was preparing them for the imminent manoeuvres. In Q3 the HUD scored 90% of positive answers highlighting that simple clear information during near-collision situations could alleviate partially the anxiety levels. However, Q4 divided the users' opinions as 50% required additional information to be displayed. The Q5 highlighted that familiarity with the user interface elements was sufficient for this type of task, scoring 90%. The Q6 statement was aimed to confirm the results of the Q2 and identify any change of opinion by the users. Their responses in Q6 however confirmed the results of Q2 scoring 80% positively with users agreeing that the HUD was offering a more relaxing experience. In turn statement Q7, reinforced the previous statements as only 20% of the users found the HUD information stressful. On follow-up feedback from the users that provided this feedback, they stated that knowing through the visual interface that a potential collision might occur and fast manoeuvring is required was panicking them.

This confirms a long-standing debate that occurs in other disciplines as well, such as medicine. In the latter, some patients would like to know all the relevant information about their treatment whilst others prefer to remain unaware [23]. In turn, 30% of the users responded in Q8 that they would like to have audio information as well. Potentially in the case that the HUD presents the visual information the addition of audio instructions might be superfluous as the driver won't be able to operate the vehicle. The additional sensory feedback through audio might increase occupants' anxiety, although this would require further research to establish the type of audio, volume, frequency and other details that might affect the results. Once more a different statement (Q9) aims to investigate further and confirm if the users were indeed more relaxed with the use of HUD. Q9 received 80% positive feedback. Finally, Q10 aimed to acquire the overall users' notion regarding their trust in autonomous driving choices and efficiency. Notably, only 20% of the users responded that they feel comfortable with AV driving and thy trust the system.

4 Conclusions

The paper presented a preliminary evaluation aiming to identify the benefits or drawbacks of information provision through AR HUD in AVs. The hypothesis that maintaining the vehicle's occupants informed about collision avoidance manoeuvres performed by autonomous driving, could reduce passengers' anxiety was tried. Ten users experienced AV driving and collision avoidance in imminent collision scenarios in a VR Driving Simulator, with and without the provision of information by a prototype HUD. The evaluation results presented that users were more relaxed knowing what will happen rather than being oblivious to the robotic driving process of the vehicle. A small percentage prefered to remain unaware. The latter group of responses is of interest for future evaluation of such UIs that could aspire to provide better user experience to a larger segment of the drivers' population. This could potentially support and increase human trust in the artificial intelligence that drives current and future AVs.

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