Learn how to operate semi-autonomous vehicles with Extended Reality

Daniele Sportillo, Alexis Paljic, Luciano Ojeda, Giacomo Partipilo, Philippe Fuchs, Vincent Roussarie

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Extended Abstract

Daniele Sportillo
PSA Group, Mines ParisTech, PSL
daniele.sportillo@mpsa.com

Alexis Paljic
Mines ParisTech, PSL
alexis.paljic@mines-paristech.fr

Luciano Ojeda
PSA Group
luciano.ojeda@mpsa.com

Giacomo Partipilo
PSA Group
giacomo.partipilo@mpsa.com

Philippe Fuchs
Mines ParisTech, PSL
philippe.fuchs@mines-paristech.fr

Vincent Roussarie
PSA Group
vincent.roussarie@mpsa.com

ABSTRACT

This paper presents an ongoing work aimed at evaluating Extended Reality training for the interaction of general public with mobile robots, with a particular focus on semi-autonomous cars.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**; **Virtual reality**; • **Software and its engineering → Virtual worlds training simulations**;

KEYWORDS

Virtual Reality, Augmented Reality, Extended Reality, Conditionally Automated cars, Training, Driving, Interaction

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1 INTRODUCTION

The advent of automated driving systems is marking a revolution in the automotive and robotic field. Conditionally automated cars will provide almost full automation in some driving scenarios like highways and traffic jams. The human driver can engage in secondary activities while the automated system is active. For these reasons, most of the time, operating this kind of vehicles does not require any particular attention because the interaction between the human driver and the car is just limited to the activation of the automated driving and the take-over action. However, these actions can lead to dangerous consequences if they are not performed in the proper way. Hence, there is the need for the drivers to be trained in advance, before the first time they drive the car, to the correct use of the on-board Human-Machine Interface. Designing intuitive HMI for autonomous cars is a necessary but not sufficient condition to ensure a correct use of this kind of systems. For this reason, our hypothesis is that a training program is crucial to ensure the correct acquisition of the interaction skills.

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Figure 1: Illustration of a user with HMD immersed in the Virtual Leaning Environment

In this context, Extended Reality (XR) represents a valuable and flexible learning tool which allows drivers to be trained in an environment that enables correction, repetition and non-dangerous failure [2] providing to the users the possibility to interact with real or surrogate equipment. Thanks to the peculiarities offered by the XR systems the training program could be performed by the customers in the car dealership as part of the handover process.

In fact, if until few years ago Virtual and Augmented Reality platforms were addressed to a niche audience, nowadays these systems are more and more accessible thanks to the process of *democratization* in progress. Technological improvements, lower prices and the ease of integration in game engines are leading to a mass spread of many XR-enabled applications.

Although there is just few work about the use of XR for this specific research question, the use of this systems has been already extensively investigated in related fields. According to the decisive findings from the aviation [9], VR and AR can be definitely used to train pilots in flight simulators with relevant results. These outcomes make us wondering if the same conclusions can be found also for the acquisition of interaction skills in semi-automated cars. In fact, from an operational point of view driving this kind of vehicles could be compared to flying a plane (in the sense that the interaction is occasional only required in certain situations); however, some important differences such as the fact that cars are operated not by professional pilots but by ordinary drivers, make this research question attractive and challenging.

a b c d

Figure 2: The three training systems: (a) the user manual displayed on the laptop computer, (b) the fixed-base driving simulator, (c) the light VR system. (d) The high-end simulator used for the test drive

Consequently, we believe that the automotive sector could boost the use of XR technologies for mass training of general public. Moreover, the use of these systems in collaboration with HMI designers [6] and driving ergonomics experts, could play a central role for road safety.

2 METHODS

In this paper we present an ongoing work aimed at exploring the potential role of Extended Reality systems to train future drivers of semi-autonomous cars. In particular, we are interested in designing an immersive educational tool to let drivers learn how to operate their vehicle in different situations. The research work consists of three parts: the design and development of an immersive virtual learning environment; a comparative study between non-immersive and immersive VR training; a comparative study to assess training effectiveness using augmented and virtual reality systems. Moreover, to validate the training system it is crucial to ensure an adequate Transfer of Training from the learning environment to the real situation. To do so, test drives with high-end driving simulators and prototypes of real vehicles are taken in consideration.

2.1 The Virtual Learning Environment

The aim of the training is to instruct the drivers to interact with a semi-autonomous vehicle. The actions we are interested to teach are activation, deactivation and partial deactivation of the automated driving system, takeover in both non-hazardous and safety-critical situations.

To do so, an immersive 3D Virtual Learning Environment (Figure 1) has been designed and developed in Unity 3D. At the beginning, an introductory video is displayed in a transitional environment. The aim of this environment is to familiarize the user with the training platform and to present the main functionalities of a general automated driving system. Afterwards, the VLE provides a simulated driving environment in which the trainee, supported by a virtual assistant, follows a step-by-step learning procedure. Each step represents a precise action to perform in a given situation.

During all the training, the trainee is virtually immersed in a 3D model of a car. The driving environment is intentionally simple: a straight road with no traffic and few elements on the sides. This choice was made to avoid that the immersive experience distracted the trainees from the learning task. To provide the possibility to perform a secondary activity during the autonomous driving phase, a virtual tablet with which the driver could interact, has been added inside the car. The tablet can be used to watch videos, visit web pages and play simple games.

2.2 The VR approach

Virtual Reality head-mounted displays have been largely used for education and training purposes [2], and also, more rarely, for drivers training [7]. Considering the need to deploy the training system to car dealerships, we do not take into consideration CAVEs and other cumbersome VR platform for our purpose.

In our work, before addressing the question of training, we compared the use of steering wheel and 6-DoF controllers for the interaction with the vehicle [8]. Even though objective measures did not provide decisive parameters to determine the most adequate interaction modality, self-report indicators showed a difference in favor of the steering wheel.

Afterwards, in a between-subject study with 60 participants, a training based on head-mounted display was compared to a user manual displayed on a laptop and to a fixed-base simulator equipped with a screen (Figure 2). The VLE was used for both the VR headset and the fixed-base simulator. The user manual contained the same information of the VLE, but in the form of slides. To evaluate the effectiveness of the training, all the participants were evaluated in a 20-minute test drive in a high-end driving simulator.

Objective measures collected during the test drive showed that the participants trained in the VLE performed better in the take-over process in terms of reaction time. Moreover, subjective measures, collected through questionnaires, suggested that the head-mounted display was a more suitable system in terms of training pleasantness and ease of understanding.

This study contributed to prove that a training based on immersive Virtual Reality systems can improve take-over performances. However, we observed that the manual driving task during the training made the participants focus more on the driving performance (speed limit, position in the lane) than on the actual learning procedure. In other words, the participants were able to learn the actions to perform (activation/deactivation of the automated driving system), but they did not pay much attention to the evolution of the HMI in the vehicle. For this reason, we planned a further experiment aimed at evaluating the impact of the driving task on the learning.

2.3 The AR approach

The next step of our research is to evaluate the potential role of Augmented Reality headsets for this specific training purpose. An AR headset would be intended to be used in a real vehicle where the car cockpit is augmented with appropriate training information. Thus, the trainee would learn how to use the interface inside the vehicle by interacting with the real equipment. The effectiveness of the training using the AR headset will be then compared to the VR headset.

Although literature proposes relevant work about the use of AR systems for educational purposes [3] and the evaluation of AR and VR for industrial training [1], when it comes to the automotive field AR platforms are usually implemented in form of head-up displays to help the drivers during the driving task [4]. An example of training program for drivers based on AR headsets is proposed by Regenbrecht et al. [5]; during a test drive with a real vehicle the trainee learns to cope with adverse road and weather conditions and simulated accident situations. In our case, since the need is to use the system in car dealerships, the training must be carried out off-road and so the possibility to drive on a track cannot be taken into consideration. Moreover, simulating a driving environment as for the training based on the VR headset, it is likely to be *counter-immersive* since the field of view of the current AR headsets is reduced and the surrounding environment remains still.

Thanks to this study, we aim at evaluating several factors. First of all, starting from the finding of the VR experiment, we are curious to understand how the driving task affects the training. By comparing AR and VR systems we aim at investigating if *learning-by-driving* can improve the skill acquisition process, or if the driving task requires a greater cognitive load which deteriorates the training performance. Also, we are interested in exploring the benefit of being surrounded by a real car and the importance to interact with the actual equipment. Finally, we will evaluate the effect to see its own body when operating the vehicle.

3 CONCLUSIONS AND PERSPECTIVES

The democratization of Extended Reality is leading to the adoption of this technology for several challenging applications, still mostly confined to a professional usage. In this paper we widen their use to the general public, by presenting an ongoing work about the use of immersive XR systems for the training of future drivers of semi-autonomous vehicles.

To address the research question, we started to travel the reality-virtuality continuum by comparing non-immersive and immersive VR systems. Currently, in order to study the effects of a more realistic representation of the training environment, we are investigating the benefits of Augmented Reality headsets for this purpose. Furthermore, to assess the transfer of training in a more ecological way, we are considering to use prototypes of semi-automated cars to evaluate user performances in the test drive after the training phase.

The preliminary results persuade us that XR platforms represent promising tools to reduce the knowledge gap between users and emerging technologies. For this reason we believe that the existing literature and the increasingly important findings in the field of Virtual, Augmented and Mixed Reality will serve as important foundation to enhance the interaction between humans and robots.

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