Eye Tracking and Immersive Environments: Analysing the Automotive Experience

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Abstract. *This study combines virtual reality and eye tracking to provide insights about a drivers' attention and perception. The study follows the Design Science Research paradigm, in which we are using Unreal Engine and PICO 4 Enterprise VR head-mounted display to develop a prototype of a virtual vehicle in an immersive environment, allowing for the analysis of eye-tracking data. Our preliminary results demonstrate that eye tracking is effective in creating heat maps, aiding in the identification of focal points and distractions. Our research contributes to enhance usability testing, user experience, and safety within the automotive industry.*

1. Introduction

Modern industry faces the need to technologically update itself to stand out in the market. As a result, manufacturing processes developed within this environment have required automation and digitalization to increase productivity within companies, a trend known as Industry 4.0. This revolution demands the use of technologies that are essential today to achieve its goals, such as Artificial Intelligence, 5G internet, Virtual Reality(VR), and cybersecurity [Schwab 2017]. These technologies are fundamental for the development of automotive manufacturing processes, including the production of in-car devices and 3D prototype models [Conceição et al. 2022]. The automotive industry currently needs to follow many steps to achieve the final product, such as market research, product planning, model creation, simulations, and usability and safety testing[Cantor et al. 2008].

Virtual Reality is considered a key component for this project, which aims to use the virtual environment to conduct usability tests within a vehicle using eye tracking to generate a heat map of the product and identify points observed by the user. Eye tracking in VR involves a system that tracks eye movements, delivering the person's gaze position in three-dimensional coordinates within the virtual reality. This technology is used in various fields, such as psychology[Holzman et al. 1974], and even in performance analysis studies of pilots in aeronautics[Dehais et al. 2017]. Currently, there are no recent works at SVR events addressing the use of eye tracking. The most recent work is the article named Rendering optimizations for virtual reality using eye-tracking[Matthews et al. 2020], published 4 years ago, which does not analyze user behavior. The primary objective is to enhance usability testing and user experience by providing insights into drivers' attention and perception through eye tracking. The article presents an analysis of the use of eye tracking within VR for the automotive industry, focusing on vehicle usability and driver safety based on driver attention, and evaluates whether VR and eye tracking can be effectively used to validate tests of new technologies implemented in cars.

In this context, our study aims to combines virtual reality and eye tracking to provide insights about a drivers' attention and perception.

The organization of the remaining parts of this paper is as follows: our materials and methods is described in Section 2, the preliminary results are analyzed and discussed in Section 3; and the final considerations are presented in Section 4.

2. Materials and methods

To guide the project steps, Design Science Research (DSR) was employed for the study's development and planning, as DSR is a strategy for creating new materials or technological devices, contributing to the advancement of future research. The research aims to deliver an artifact, following the six steps of DSR: (1) Problem Identification and Definition; (2) Solution Objectives; (3) Artifact Development; (4) Artifact Evaluation; (5) Artifact Refinement; and (6) Communication of Results.

For the first three steps, a literature review was conducted for steps (1) and (2) to understand the problem and assess whether the objectives are achievable. Additionally, a software search was performed to initiate step (3)[Novotný et al. 2022]. Subsequently, for the validation of tests in step (4) and the refinement of the artifact in step (5) to finally reach the final result (6), efficient verification methods are required to ensure the experiment's success.

To create the virtual world, Unreal Engine was used, as it was deemed superior to competitors in maintaining project realism. For greater immersion in virtual reality, it is essential to use a VR headset integrated with eye-tracking technology; hence, the PICO 4 Enterprise was selected. With the technologies defined, an immersive virtual environment was developed within Unreal Engine to meet the basic needs of the eye-tracking test prototype within a vehicle. With the prototype ready, the development of the artifact progresses, leading to the eventual dissemination of the final results obtained.

3. Partial results

Following the development of the artifact, eye-tracking data was successfully acquired and analyzed with accuracy. With the eye-tracking fully operational, an immersive virtual environment resembling the interior of a vehicle was developed for simulating and testing the use of eye-tracking technology. Based on the generated data, a heat map was created to highlight the most observed areas by the user, ensuring whether the person's focal points align with the company's objectives.

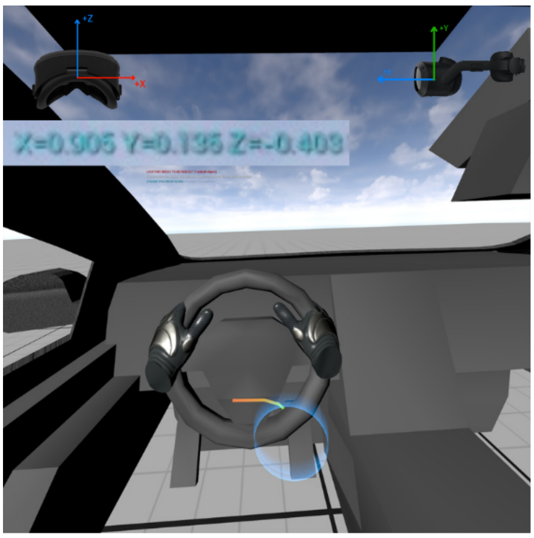
3.1. Eye Tracking

The virtual environment was created with the primary goal of acquiring eye-tracking data, which involves receiving information about the pupil's position relative to the plane of the headset and translating it into a gaze position based on three-dimensional coordinates x, "y," and "z." The dimensions provided by the headset correspond to the final eye-tracking position, where ”x” and ”y” represent the two-dimensional Cartesian coordinates of the pupil within the virtual reality headset, and ”z” is the vector that represents the final gaze direction within the VR environment. With this, it is clear that understanding eye tracking is of utmost importance for achieving the goal of creating heat maps, providing a clearer visual understanding of the user’s gaze (Figure 1).

Figure 1: Example of a heat map in virtual reality

3.2. Development of the Environment with VR

With the completion of the eye-tracking development, the project moved to the second phase, which involved creating the basic environment for user interaction and integrating a vehicle model with essential features for focal analysis of eye tracking within VR. The environment includes a view of the main dashboard of a car model, as illustrated in the image showing the virtual environment developed from the vehicle’s perspective. Additionally, a laser is present, representing the eye tracking used within the vehicle, utilizing the PICO 4 Enterprise virtual reality headset (Figure 2). For more information, a supplementary video is available at `https://youtube.com/shorts/zHAiAgCsu4g`.



(a) Eye tracking in action

(b) Use of the PICO 4 Enterprise for VR

Figure 2: Testing eye tracking in virtual reality

4. Final Considerations

Based on the data acquired and the information collected in this study, it is possible to assert that eye tracking is a powerful tool for obtaining crucial data, such as analyzing users' perceptions of distractions and focal points. The project aims to advance technology, ensure that research in this area is diversified, and simultaneously guarantee driver safety. The research also seeks to expand knowledge about virtual reality and its applications in Industry 4.0, and it is understood that this will be valuable for future researchers in understanding the use of eye tracking in various fields. For the next steps of the research, a system will be studied and developed within VR to generate a heat map based on the acquired eye-tracking data, making it possible to conduct more in-depth analyses.

5. Acknowledgements

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References

Cantor, B., Grant, P., and Johnston, C. (2008). *Automotive engineering: lightweight, functional, and novel materials*. CRC press.

Conceição, I. C., Barbosa, M. O., Teixeira, R. L. P., and Silva, P. C. D. (2022). Os discursos sobre a indústria 4.0 no setor de estampagem da indústria automobilística: uma revisão sistemática da literatura. *Revista de Casos e Consultoria*, 13(1).

Dehais, F., Behrend, J., Peysakhovich, V., Causse, M., and Wickens, C. D. (2017). Pilot flying and pilot monitoring's aircraft state awareness during go-around execution in aviation: A behavioral and eye tracking study. *The International Journal of Aerospace Psychology*, 27(1-2):15–28.

Holzman, P. S., Proctor, L. R., Levy, D. L., Yasillo, N. J., Meltzer, H. Y., and Hurt, S. W. (1974). Eye-tracking dysfunctions in schizophrenic patients and their relatives. *Archives of general psychiatry*, 31(2):143–151.

Matthews, S. L., Uribe-Quevedo, A., and Theodorou, A. (2020). Rendering optimizations for virtual reality using eye-tracking. In *2020 22nd symposium on virtual and augmented reality (SVR)*, pages 398–405. IEEE.

Novotnỳ, J., Machan, J., and Orlickỳ, A. (2022). Eye-tracking technology in automotive industry. *Acta Polytechnica CTU Proceedings*, 39:49–54.

Schwab, K. (2017). *The fourth industrial revolution*. Crown Currency.