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# Visual Assistance in VR-based Robot Control: Towards a Reproducible Evaluation Scenario

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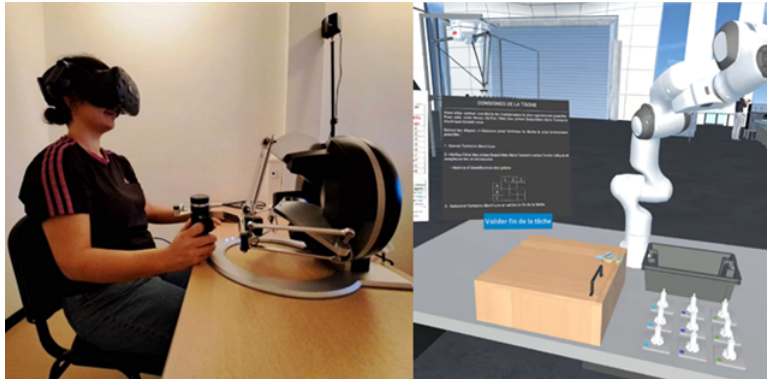


Figure 1: In our experiment, we placed participants in a remote robot control task using a VR headset and teleoperation device (left). They completed an industrial maintenance scenario in three visual assistance conditions (right).

## ABSTRACT

Immersive technologies enhance industrial applications by creating virtual representations of manufacturing environments and providing visual assistance for tasks. Most studies in the literature are based on ad hoc scenarios, making comparison across studies challenging. In this research, 99 participants controlled a remote industrial robot using a VR headset in a reproducible maintenance task. They performed the task under three conditions: without assistance (control), text-based assistance, or attentional cueing (highlighting objects). We manipulated task difficulty (easy versus difficult) and assessed performance based on completion time and failure rate. Results showed visual assistance significantly shortened task completion time, with findings discussed.

**Index Terms:** Virtual Reality, Human Performance, Head-Up Display, Attention Cueing, Industry 4.0

## 1 INTRODUCTION

Manufacturing is evolving with Industry 4.0, driven by advances in information technology. Immersive technologies improve operators' perception and cognition by delivering contextual information through head-up displays [6]. Delivering multimodal information, such as haptic and visual cues, enhances operator performance. However, it is crucial to evaluate these systems for operators' adoption, effectiveness, and trust in new technologies [7].

Numerous studies evaluating these systems have been published, highlighting different types of measurements, tasks, or technologies (e.g. in [1, 5]). However, these studies provide difficult results to reproduce and compare due to the diversity of studied industrial tasks.

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For this reason, recent research [4] provided a reproducible industrial task (based on an electric socket maintenance scenario) to assess human performance in industry 4.0 use cases. This scenario benefited from a cognitive task analysis aimed at reproducible experimental protocol (see section 4 for more details). The contribution of this work is to provide the first empirical assessment of this scenario by verifying whether it can discriminate the effect of the presence or absence of visual assistances on task performance.

The present study builds upon the work from Desvergnès et al. [4] and uses a specific use case of VR-based remote robot collaboration with two possible visual assistance modes offered through a virtual Head-Up Display. We aim to report the first data collected about human performance with such a protocol.

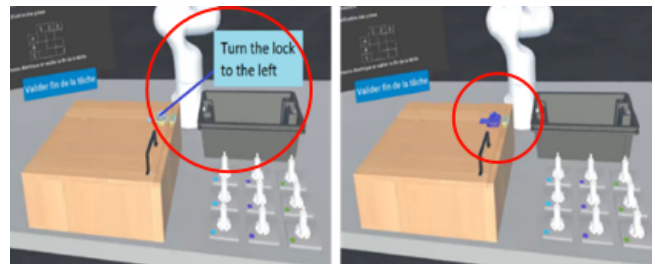


Figure 2: The two visual assistance conditions (signaled by red circles). Left: Text instructions are displayed next to the next relevant object. Right: the next relevant object is highlighted. The next relevant object changes as the task progresses.

## 2 METHODOLOGY

### 2.1 Participants

Ninety-nine participants were involved in the study, including 87 females, 11 males, and one individual who did not identify as ei-

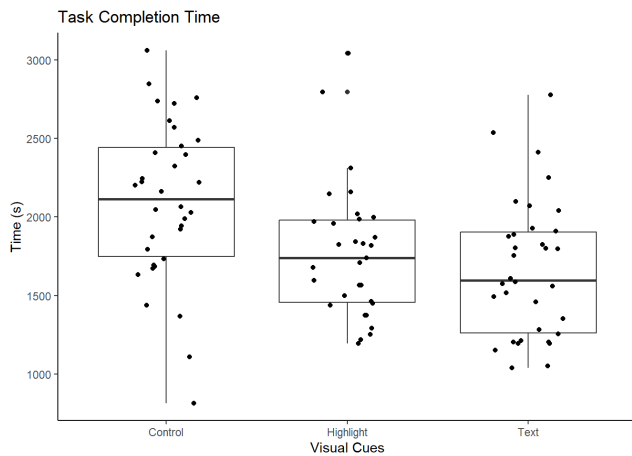


Figure 3: Participants in the assistance conditions completed tasks significantly faster than those in the control group.

ther. Their ages ranged from 17 to 44 years ( $M = 18.8$ ,  $SD = 2.83$ ). The study followed local ethical guidelines and GDPR regulations. Participants had normal or corrected-to-normal vision, excluding those with color blindness. All participants completed the Simulator Sickness Questionnaire (SSQ) before the experiment.

## 2.2 Apparatus

The experimental task was conducted in a virtual environment using the HTC Vive Pro EYE headset, which features dual AMOLED 3.5" screens, a 2880 x 1600 pixels resolution, a 90Hz refresh rate, and a 110° field of view (See Figure 1). The virtual environment, designed with Unity, simulated a factory with a workbench, an electrical cabinet, and a virtual representation of the Franka Emika robot that participants controlled for the task.

## 2.3 Task and assistance

The experimental task involved controlling a remote robot using a VR headset and haptic interface in a technical maintenance scenario [4] (see section 4). Participants completed the task by inspecting the sockets in five cabinets as quickly as possible. The virtual environment provided two types of visual assistance (see Figure 2), selected from this review [6].

The study included two between-subject factors: the complexity of instructions, which had two levels ("easy" and "difficult" conditions), and three different visual assistance modalities. The first, "text," consisted of a 2D element linking labels to the task's relevant objects and offered additional text instructions to guide motor action and decision-making. The second type, "highlight," visually highlights specific objects with a blue overlay for attentional guidance. The control group performed the task without assistance.

## 3 RESULTS

### 3.1 Completion Time

A two-way ANOVA analysis, realized on successful trial completion time, revealed a main effect of the types of visual assistance,  $F(2, 93) = 7.79$ ,  $p < .001$ ,  $\eta^2 = 0.141$  (Figure 3). Participants required more time to complete the task in the "control" group ( $M = 2096$ ,  $SD = 79.4$ ) than in the "highlight" group ( $M = 1777$ ,  $SD = 83.2$ ), or in the "text" group ( $M = 1668$ ,  $SD = 79.4$ ). Post-hoc Bonferroni tests revealed significant differences between the control group and visual assistance conditions. There was no difference between the two types of assistance. There was no effect involving task complexity.

### 3.2 Failure Rate

A two-way ANOVA revealed a main effect for the complexity level,  $F(1) = 5.79$ ,  $p = .018$ ,  $\eta^2 = 0.054$ . Participants more often failed in the "difficult" group ( $M = 26.9$ ,  $SD = 24$ ) than in the "easy" group ( $M = 16$ ,  $SD = 21.4$ ). There was no effect on the visual assistance conditions and the failure rate.

## 4 DISCUSSION AND CONCLUSION

As expected from previous research, task completion times were significantly shorter with both assistance types than in the control group (e.g., in [2]). Also, increasing task difficulty impacted the number of failures. Those results demonstrate that our industrial task is sensitive enough to discriminate task instructions difficulty and contextual assistance. This protocol can be used to evaluate new interactions within a reproducible framework.

This research was a first step toward a more reproducible methodology to assess human performance in immersive technologies for the industry. Limits of this work include the participants' sample (here, mostly female students although men were evenly distributed in each group) and the intrinsic difficulty of the task, which might need to be higher. Future research should focus on the ecological aspects of the task and performance metrics [3] and explore the impact of additional assistance types.

## SUPPLEMENTAL MATERIALS

Task specifications are available at: [https://osf.io/svkrw/?view\\_only=cef824e5e5604122be6790f80324547f](https://osf.io/svkrw/?view_only=cef824e5e5604122be6790f80324547f).

## ACKNOWLEDGMENTS

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