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Perception of Visual Realism and Acuity in Real vs. Immersive Virtual Reality Scenes

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Abstract

With the significant developments of extended reality (XR) technologies, the evaluation of the fidelity and practical applicability of immersive virtual reality (IVR) in replacing real-world shopping tasks is becoming increasingly important. In this paper, a virtual environment (VE) was used with a state-of-the-art head-mounted display (HMD) to evaluate participants' visual perception of IVR compared to reality. A visual acuity test demonstrates that in the IVR, participants experienced a significant decline of 37.1% compared to their real-world eyesight test score. Additionally, participants were asked to compare real furniture with their counterparts in an IVR, to complete Likert-scale questions assessing their perception of visual realism. This study initially reveals that IVR has the ability to convey the basic visual information of displayed virtual furniture objects.

CCS Concepts
• ***Human-centered computing*** → ***Empirical studies in HCI;*** • ***Computing methodologies*** → ***Virtual reality;***

1. Introduction

Extended reality (XR) has shown promising applications across various fields. However, recent research shows that even with high-performance head-mounted displays (HMDs), the constructed virtual environments (VEs) are still significantly different from the real-world experience [HW23]. Among those, one key question has yet to be systematically explored: to what extent do users perceive the objects they see in IVR as "real"?

Recent work has started to explore the visual acuity in both real and VEs. The effectiveness of visual acuity tests in VR compared to the real world is studied in [ASK24]. Participants are asked to conduct the experiment without vision correction, meaning that participants are required to perform the task without glasses or any other visual aids. The study in [AAKB*19] reveals no significant difference in the perception of lighting and its impressions, but significant differences are found in the assessment of visual-quality attributes. Also, the responses are reported to be affected by the limited resolution of the VR headset. Work on HMD systems has demonstrated the feasibility of measuring dynamic visual acuity in immersive environments [KSLK19]. A detailed overview of dynamic and static visual acuity charts and [CGIW21] for the landscape of digital self-assessment tools is described by [ST24].

Therefore, the presented user study aims to explore the sense of reality in IVR from a visual level, examining to what extent users perceive the objects they see as real representations with glasses that correct their vision. A user experiment is conducted, including a real-world visual acuity test and its comparison with a virtual visual acuity test in IVR using one of the world's highest-resolution HMDs. In the experiment setup, it was found that even with high-resolution HMDs, human visual acuity is still significantly impaired compared to the real world.

2. Experiment Design

A total of 21 volunteering participants received an introduction to the experiment. They completed a visual acuity test in the real environment and VE, followed by a visual comparison between physical and virtual furniture. The experiment was conducted using the Varjo XR-3, a state-of-the-art headset. The VE was implemented in Unity using the High Definition Render Pipeline (HDRP) to approximate the real space illumination.

2.1. Task I: Visual Acuity Eyesight Test

The Snellen visual acuity test [CGIW21] was employed to assess participants' vision performance in both the real world and the VE. The Snellen chart was printed on A4 paper and positioned at eye level, with a viewing distance of three meters. Both VR and real-world visual experiences rely on binocular vision. The smallest line a participant could successfully identify is recorded as the measured visual acuity level.

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2.2. Task II: Visual Realism Evaluation

To assess participants' perception of the realism of the virtual furniture, real and virtual furniture were displayed to the users, as shown in Figure 1. Figure 1b appears darker than Figure 1a, due to the lighting and rendering settings, despite the efforts to match the VR illumination to real-world conditions. Participants' subjective perception is captured by a 7-point Likert scale questionnaire, which is inspired by the German VR Simulation Realism Scale [PD13].

(a) Real Furniture (b) Virtual Furniture

Figure 1: *The furniture in reality and its corresponding digital model in VR: (a) real furniture (b) virtual furniture.*

3. Results

3.1. Part I: Visual Acuity Eyesight Test Results

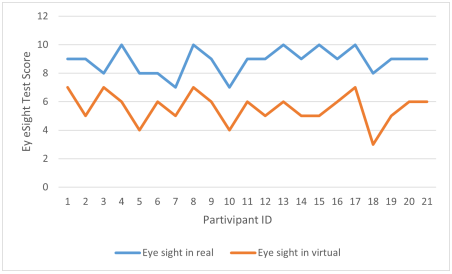

Figure 2: *Comparison of visual acuity test results of all 21 participants between the real and VE.*

As shown in Figure 2, all participants achieved a higher eyesight test score in real-world settings (average score = 8.86) compared to the VE (average score = 5.57), experiencing a 37.1% decline in VR visual acuity scores. This indicates that the VR scene could not yet fully replicated the real-world visual acuity. By employing a Wilcoxon Signed-Rank Test, it was confirmed that a statistically significant difference exists ($p < 0.05$) between the test scores of the real world and VR scene.

3.2. Part II: Visual Realism Evaluation Results

The average scores of the 21 participants for the first five questions in the questionnaire are shown in Figure 3. Most scores are above four on the 0–6 Likert scale, in terms of coloring, material appearance, proportions, and overall comfort, while lighting realism received a slightly lower score.

4. Conclusions and Future Work

Visual acuity results show that participants' visual performance in VR was lower than in reality, highlighting potential limitations of current state-of-the-art VR devices in providing visual realism.

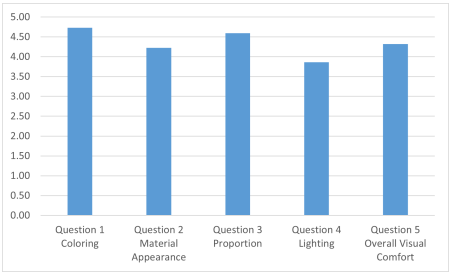

Figure 3: *Average score from 21 participant ratings (0–6 Likert scale), evaluating visual realism, including coloring, material appearance, proportions, lighting, and overall visual comfort.*

Additionally, participants reported that virtual furniture was generally perceived realistic, effectively displaying color and proportion. However, only a limited number of objects were considered, which may not be sufficient to capture the diversity of colors, materials, and shapes found in reality. Also, most importantly, more precise lighting condition control is required to eliminate the effect the perceived difference in lighting might have had on the results. Future work could focus on achieving more precise control of lighting conditions and on revealing users' perceptual responses to differences across rendering pipelines.

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