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METHODS FOR USING IMMERSIVE VIRTUAL REALITY FOR EXPERIMENTAL STUDIES IN LIGHTING RESEARCH

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Abstract

1. Motivation and objective

Due to the growing popularity of virtual reality (VR) as a tool for conducting subjective experiments, we propose a session addressing methodological concerns and good practices for the use of VR in lighting research, going further than a simple demonstration of immersive scenes. In view of the emergence of this technology as an experimental tool in lighting studies, it is important to document and establish a reference workflow, introducing potential pitfalls and suggested practices to obtain reliable data.

This presentation will introduce the key elements for the design and conduction of experimental studies using VR -ranging from the creation of the immersive scenes to the particularities of collecting data when the participants are immersed in a virtual environment-, coupled with demonstrations through a virtual reality headset.

2. Key elements in experimental studies using virtual reality

This section introduces the key elements for experimental studies where the visual stimulus is controlled and presented through a VR headset, categorized based on their relevance to the independent and dependent variables used in experimental lighting research, and a wider discussion about the application of this technology in lighting research.

2.1 Independent variables

In experimental studies where the stimulus is one the experimental variables, it is essential to ensure the **fidelity of the visual stimulus**. The same good practices from lighting research using other virtual representation methods, where the virtual luminous environments are generated through methods that provide accurate photometric data such as **physically based simulation** or **high dynamic range photography**, apply also for virtual reality scenes. Due to the limited luminance range of the device display, the choice and application of **tone-mapping operators** and **gamma correction** are of particular importance to ensure that the researcher has control over the scene that the participant is exposed to. Lastly, when using another software to project the immersive scene in the virtual headset, such as Unity, it is necessary to ensure that **no other light sources are present**; all lighting in the immersive scene should be derived from the photometrically accurate method of generating virtual environments that was chosen by the researcher.

Contrary to experiments using a stimulus in the real environment –such as a paper survey, or exposure to a real or virtual stimulus in the real environment-, in the case of VR the participant is fully immersed in the virtual environment. While this can greatly increase the perceived presence and realism in the virtual environment, it also introduces complexity regarding **the perception of the visual stimulus from the participant**. A notable aspect that impacts the realism of the immersive virtual scene is the **perception of depth**. This can be achieved through different **environment mapping methods** in virtual reality; for example, current advances in the Radiance lighting simulation software allow the creation of omni-directional stereoscopic content, which ensures the perception of depth for all view directions in a 360° scene**.** Other factors that can negatively affect the participant's perception of the virtual stimulus is the **usability of the immersive virtual environment**, which could cause **motion sickness** and can be minimized through choices regarding the content and quality of the presented scenes. Similarly, **external stimuli** such as noise and temperature can influence the perception of the virtual scene, and should be monitored and controlled to a comfortable range during the experimental session.

2.2 Dependent variables

The collection of **subjective evaluations** from the participants presents some particularities in virtual reality. Since participants are immersed in a virtual environment, they cannot interact with a physical questionnaire. An alternative is a **verbal questionnaire**, where the researcher asks the questions, introduces the rating scale, and records the participant's responses. In the authors' studies using a verbal questionnaire, **simpler rating scales with intuitive ranges** (such as 1 to 5, or 1 to 10) were preferred to more frequently used ones (such as 1 to 7). Similarly, participants preferred to use **numbers rather than verbal qualifiers** (such as 'slightly', 'moderately', 'very') to evaluate the stimulus when they did not have a visual reference of the rating scale. Another solution is the use of **visual references**; either through an interactive questionnaire, or a visual representation of the verbal questionnaire, shown in VR. However, this solution affects the reliability of **head-tracking data** -where participants looked towards in VR-, as they will react to the presented question along with the virtual scene.

The immersion of the participant in virtual reality also greatly facilitates the collection of **physiological measurements**. In addition to the participant's head movements, which can be obtained from the VR headset, devices measuring physiological indices such as skin conductance or electroencephalography data can be used, as the time of exposure to the stimulus in VR can be recorded with a very high precision. It is however is essential to ensure the **synchronization of collected data with the exposure to the visual stimuli**.

3. Applications and limitations of VR as an experimental tool in lighting studies

Recent studies have shown the validity of virtual reality as both an educational and an experimental tool to investigate the perception of luminous environments, highlighting the potential of this technology for lighting research. However, the limited luminance range of current VR headsets does not allow the creation of conditions that can induce discomfort. Moreover, further work is needed to investigate the effect of various parameters on the realism of the virtual environment in VR, such as the effect of color and the level of detail.

4. Outcome

This presentation aims to provide a reference for the development and conduction of experimental studies using VR in lighting research, coupled with a hands-on experience of immersive virtual scenes. Furthermore, it will introduce and address methodological concerns for the use of VR in research, covering the key elements related to the experimental variables and the limitations of this technology.