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Comparison of Light Field and Conventional Near-Eye AR Displays in Virtual-Real Integration Efficiency

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ABSTRACT

Most existing wearable displays for augmented reality (AR) have only one fixed focal plane and hence can easily suffer from vergence-accommodation conflict (VAC). In contrast, light field displays allow users to focus at any depth free of VAC. This paper presents a series of text-based visual search tasks to systematically and quantitatively compare a near-eye light field AR display with a conventional AR display, specifically in regards to how participants wearing such displays would perform on a virtual-real integration task. Task performance is evaluated by task completion rate and accuracy. The results show that the light field AR glasses lead to significantly higher user performance than the conventional AR glasses. In addition, 80% of the participants prefer the light field AR glasses over the conventional AR glasses for visual comfort.

KEYWORDS

3D Display, Augmented Reality, Mixed Reality, Near-Eye Display, Psychophysics, Psychovisual, Vergence-Accommodation Conflict, Visual Search

INTRODUCTION

Existing augmented and virtual reality (AR/VR) devices often suffer from vergence-accommodation conflicts (VAC). Accommodation refers to the adjustment of focal length of a human eye to obtain a clear image of an object, whereas vergence refers to the simultaneous movement of both eyes towards or away from one another in order to align the two retinal images of an object on corresponding retinal points of interest. Consistent accommodation and vergence cues received by the brain can guide the eyes to properly focus on the object. A vergence-accommodation conflict (VAC) occurs when the brain receives mismatching vergence and accommodation cues (Figure 2), which can cause binocular fusion difficulty, visual fatigue, and dizziness to users of augmented and virtual reality (AR/VR). The conflict is more pronounced when the virtual object is closer to the eyes.

Conventional augmented reality (AR) optical see-through displays render stereoscopic images on 2D image planes. These displays are notable for lacking the ability to provide correct focus cues for

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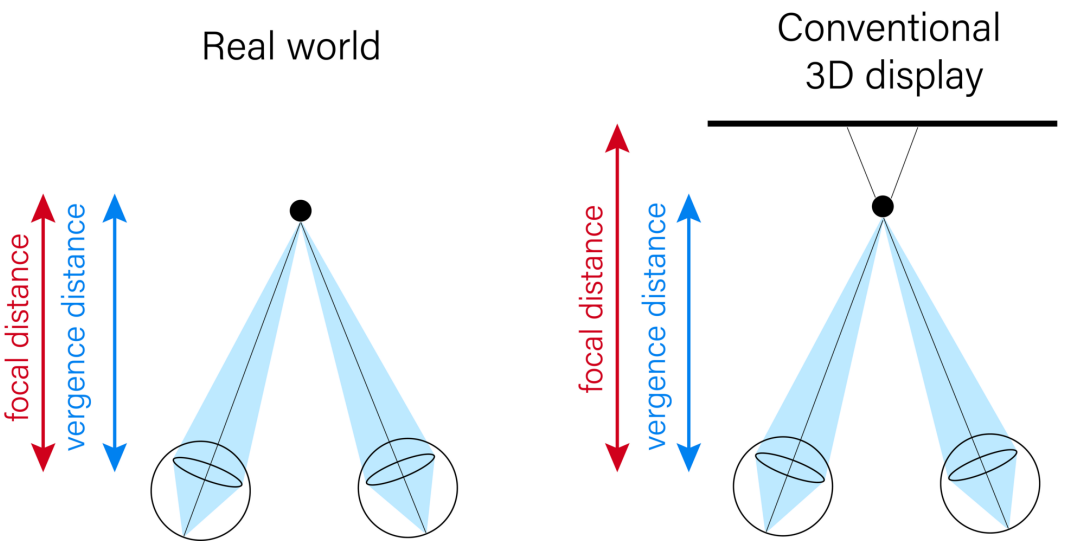
Figure 1. We present a series of text-based visual search tasks to systematically and quantitatively test human visual performance under the influence of vergence-accommodation conflict (VAC). From left to right: experimental setup, example visual content, and experimental results. Each visual content example includes two side-by-side text blocks. The left text block is displayed by a smartphone, and the right text block by a pair of AR glasses.

Figure 2. Illustration of the vergence-accommodation conflict. The eyes accommodate and converge at the same distance when watching a real object. But this is not the case when using a conventional 3D AR display.



both accommodation and convergence. Unlike traditional stereoscopic techniques, light field displays, which are VAC-free, work by generating a light field pertaining to a virtual object and projecting it into the user's eyes in the same way as the light field of a real object would travel to the eyes. A light field is a collection of light rays traveling from every point in the space of interest through every possible path (Levoy & Hanrahan, 1996). Since the light field display has continuous focal planes, the user can perceive a clear image of the virtual object at any depth.

The effect of VAC on users has been investigated for conventional AR glasses. While most of the work focuses on the physiological discomfort of users (Hoffman et al., 2008; Shibata et al., 2011; Zou et al., 2015), only a limited amount of work has examined the association between VAC and user visual performance (Gabbard et al., 2019; Daniel & Kapoula, 2019). Furthermore, light field AR display has never been considered in these studies. This motivates us to carry out the research further.