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Effects of low stereo acuity on performance, presence and sickness within a virtual environment

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Abstract

To examine the effect of stereo vision on performance, presence and oculomotor disturbances within a virtual environment (VE), two groups of 23 participants (good stereo acuity/low stereo acuity) were evaluated. Groups were matched in terms of gender, age and VE design factors (the latter were accounted for to ensure a similar VE experience between groups). Participants were immersed in a VE maze for up to 1 h during which time they interacted with the environment while performing a number of stationary and movement-based tasks. Individuals with low stereo acuity traveled further to complete two tasks in the VE, yet performance time on these tasks was comparable to participants with good stereo acuity. Although participants with impaired stereo vision likely did not fully benefit from a stereoscopic view of the scene, they may have received sufficient depth information from movement-based cues to efficiently accomplish these tasks in a comparable amount of time. Overall performance, based on both the number of tasks completed and the total translational distance moved (based on input device movement) within the VE was not hindered for those with low stereo acuity. In addition, the expected increase in oculomotor disturbances for this group was not evident in this study, and both groups reported comparable amounts of presence from VE exposure. These results suggest that when head tracking is included as part of the VE experience (i.e., motion parallax cues exist), participants with low stereo acuity can be expected to perform comparable to normal sighted individuals, experience a comparable sense of presence, and report no increase in adverse effects when viewing scenes via stereoscopic displays. Thus, motion parallax cues may adequately provide a sense of depth within a VE, and alleviate theorized performance decrements for individuals with low stereo acuity. The results of this study have implications for those designing entertainment simulations or other such applications open to the general public, where people with low stereo acuity may routinely participate.
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1. Introduction

One of the primary advantages of virtual environment (VE) technology is its ability to provide a three-dimensional (3D) perspective to viewers. This enhanced 3D perspective is created by adding retinal disparity (the stimulus of stereopsis) to the visual scene and viewing the scene through polarizing filters, shutter glasses or a head-mounted display (HMD) (Wann et al., 1995). By presenting the two eyes with images slightly displaced in the horizontal plane (laterally displaced), objects within the scene appear "as single (perceptually fused) and standing out in depth from other portions of the [scene]" (Patterson and Martin, 1992, p. 669).

Depth perception is of great importance when completing tasks in the real world (Barfield et al., 1999; Cutting, 1997; Howard and Rogers, 1995; Rinalducci, 1996; Wann et al., 1995). Traditional visual displays (i.e., desktop monitors) use pictorial cues to provide depth cues. Object interposition, size constancy, linear perspective and relative size are all types of depth cues that can be created in a two-dimensional (2D) view

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to aid in determining relative depth between objects in a visual scene. When movement is added to the visual scene, depth perception may be improved through movement-based cues (e.g. motion parallax). These movement-based depth cues are useful for determining the relative space between objects at any distance from an observer. When viewing close objects (within 3 m), individuals may also use oculomotor cues to perceive depth. Accommodation (a change in the shape of the lens of the eye) and convergence (an inward turn of the two eyes to focus on close objects) coordinate with one another to bring close objects into focus. Through one's ability to sense the position of one's eyes and the tension in one's eye muscles (Goldstein, 1999), one is able to relate these cues to distance.

At close distances (i.e., within 3 m), binocular vision is also a key contributor to depth perception. In VEs, stereoscopic displays are designed to mimic disparity (i.e., the lateral difference in perception between two retinal images) that occurs when natural scenes are viewed (Patterson and Martin, 1992). To create this effect, two images that are laterally displaced views of the same scene are presented to an observer, one image to each eye. An observer with normal vision is then able to fuse these two retinal images together, and a 3D view of the scene is perceived (Patterson and Martin, 1992; Sollenberger and Milgram, 1993). By adding binocular disparity to the visual scene, an "enhanced perception of relative depth" is produced (Patterson et al., 1992, p. 655), as users may use this additional depth cue to "actualize relative depth…when the observer is stationary" (Yeh and Silverstein, 1992, p. 583).

At least 12% of the population has some type of problem with binocular vision (Optometrists Network, 2003), which often results in partial or total loss of stereoscopic vision and binocular depth perception. This may cause concern when viewing virtual images via a visual display that relies on stereo presentation and binocular disparity. Because spatial locations of objects in a static image are often ambiguous when stereoscopic depth information is not available (Drascic, 1991), individuals that have a decreased ability to see binocular disparity due to optical or neural deficits have limited access to this effective source of depth information, and would not benefit from stereoscopic displays as much as humans with normal stereopsis (Davis and Hodges, 1995).

The current research was designed to evaluate the VE experience reported by individuals unable to effectively see binocular disparity based on the Titmus stereotest (Fricke and Siderov, 1997), a clinical depth perception evaluation. The results of this study may be especially important for the entertainment industry, where people with low stereo acuity may routinely participate in VE entertainment systems. Differences in interaction experienced between those unable to effectively see binocular disparity and those with good stereo acuity may be identified, and specific aspects of the VE experience which are affected by binocular disparity (i.e. performance time and distance, reported sickness, sense of presence) may be determined. If experiences vary greatly between the two groups (low stereo acuity and normal vision), guidelines may be presented outlining what effects are expected if individuals with low stereo acuity participate in VE experiences.

2. Background

Depth perception refers to one's ability to determine relative and absolute distances within a visual scene. A common approach to studying depth is the cue approach, which correlates 2D information on the retina with depth in the environment. According to Cutting (1997), the distance an object is away relative to an observer determines which depth cues will be utilized in determining depth. A review of the four main categories of depth perception cues (pictorial cues, movement-produced cues, oculomotor cues and binocular disparity), and their effectiveness in VEs is briefly stated below.

2.1. Pictorial cues

Pictorial cues are "probably the most important cues to depth in simulator displays of all kinds" (Rinalducci, 1996, p. 336). Pictorial cues are effective at any distance from the observer, and can be displayed on a 2D visual display. Thus, these cues are readily used in both VEs and traditional displays, and their effectiveness is unaffected by low binocular vision. Although pictorial cues do not provide absolute depth information (Cutting, 1997), experience with the pictorial cues within a visual scene may increase the accuracy of depth estimation using pictorial cues.

2.2. Movement-produced cues

Motion cues, such as motion parallax, deletion and accretion, are monocular cues, and can thus be used in both VEs and traditional 2D visual displays. As with pictorial cues, these cues are also unaffected by low binocular vision. Barfield et al. (1999, p. 239) found that when head tracking was present within a VE setting, performance time on task was similar for both monocular and stereoscopic displays, and noted that "motion parallax cues may be of greater benefit in sparse visual scenes than binocular disparity cues."

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