Multisensory Integration With a Head-Mounted Display: Background Visual Motion and Sound Motion

William J. Harrison, Matthew B. Thompson, and **Penelope M. Sanderson,**
The University of Queensland, St Lucia, Queensland, Australia

Objective: The aim of this study was to assess how background visual motion and the relative movement of sound affect a head-mounted display (HMD) wearer's performance at a task requiring integration of auditory and visual information. **Background:** HMD users are often mobile. A commercially available speaker in a fixed location delivers auditory information affordably to the HMD user. However, previous research has shown that mobile HMD users perform poorly at tasks that require integration of visual and auditory information when sound comes from a free-field speaker. The specific cause of the poor task performance is unknown. **Method:** Participants counted audiovisual events that required integration of sounds delivered via a free-field speaker and vision on an HMD. Participants completed the task while either walking around a room, sitting in the room, or sitting inside a mobile room that allowed separate manipulation of background visual motion and speaker motion. **Results:** Participants' accuracy at counting target audiovisual events was worse when participants were walking than when sitting at a desk, $p = .032$. Compared with when they were sitting at a desk, participants' accuracy at counting target audiovisual events showed a trend to be worse when they experienced a combination of background visual motion and the relative movement of sound, $p = .058$. **Conclusion:** Multisensory integration performance is least effective when HMD users experience a combination of background visual motion and relative movement of sound. Eye reflexes may play an important role. **Application:** Results apply to situations in which HMD wearers are mobile when receiving multimodal information, as in health care and military contexts.

INTRODUCTION

Optical see-through head-mounted displays (HMDs) superimpose a continuous representation of visual information in the forward field of view, which can be convenient when work requires mobility (Laramee & Ware, 2002; Liu, Jenkins, & Sanderson, 2009; Sanderson et al., 2008). For example, HMDs have been shown to facilitate patient monitoring in operating theaters: HMD-wearing anesthesiologists spend more time attending to the patient if patient information is displayed on an HMD compared with traditional monitors alone (Liu, Jenkins, Sanderson, Watson, et al., 2009).

If auditory information is needed in addition to HMD-based information, however, it is unclear how the auditory information can be presented to the HMD wearer in a compelling yet cost-effective way. Extending the aforementioned example, anesthesiologists are required to monitor a patient's blood oxygen level via pulse oximetry, which consists of a visual waveform and an auditory tone from the monitor. If an anesthesiologist chooses to view the pulse oximetry waveform via HMD, then integration of HMD-based information with auditory information is important. In addition, very little research has been done on the effect of self-motion on people's ability to bind visual and auditory information under such circumstances.

Projecting a sound to the exact physical location of a virtual visual object on an HMD is difficult. Such sound projections require calculating the perceived location of the HMD

Address correspondence to Professor Penelope Sanderson, School of Psychology, The University of Queensland, St. Lucia QLD, Australia 4072; pennys@itee.uq.edu.au. ***HUMAN FACTORS,*** Vol. 52, No. 1, February 2010, pp. 78–91. DOI: 10.1177/0018720810367790.