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Virtual reality induced symptoms and effects (VRISE): Comparison of head mounted display (HMD), desktop and projection display systems

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Abstract

Virtual reality (VR) systems are used in a variety of applications within industry, education, public and domestic settings. Research assessing reported symptoms and side effects of using VR systems indicates that these factors combine to influence user experiences of virtual reality induced symptoms and effects (VRISE). Three experiments were conducted to assess prevalence and severity of sickness symptoms experienced in each of four VR display conditions; head mounted display (HMD), desktop, projection screen and reality theatre, with controlled examination of two additional aspects of viewing (active vs. passive viewing and light vs. dark conditions). Results indicate 60–70% participants experience an increase in symptoms pre–post exposure for HMD, projection screen and reality theatre viewing and found higher reported symptoms in HMD compared with desktop viewing (nausea symptoms) and in HMD compared with reality theatre viewing (nausea, oculomotor and disorientation symptoms). No effect of lighting condition was found. Higher levels of symptoms were reported in passive viewing compared to active control over movement in the VE. However, the most notable finding was that of high inter- and intra-participant variability. As this supports other findings of individual susceptibility to VRISE, recommendations are offered concerning design and use of VR systems in order to minimise VRISE.

Keywords: Virtual reality; Display technologies; Sickness

1. Introduction

In the early 1990s there was a rapid increase in the development of commercial virtual reality (VR) systems and expectation of widespread application of the technology in industrial, public and domestic environments. At that time the interest was mostly in systems using head mounted displays (HMDs) and datagloves for personal viewing and interaction with a virtual environment (VE). So-called non-immersive systems, which display the VE on a standard PC monitor, were often not regarded as 'true' VR. Interest in VR applications led to speculation of potential side-effects from using these systems, ranging from anecdotal reports of flash-backs producing driving difficulties post-exposure to scientific reports of 'simulator sickness' following participation in VR [18,30,39].

However, in recent years the focus of display technologies has moved from HMD based systems to projection displays. Projection displays have the advantage of the potential for collaborative viewing and interaction and are an attractive financial option as the technologies can often have multiple uses rather than requiring expensive purchase of dedicated VR displays. This paper presents a series of studies examining projection based VR display systems.

1.1. Health and safety implications of virtual reality

Early work into VR health and safety established a number of findings relating to the health and safety implications

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of virtual reality [26,6]. Firstly, a framework of factors influencing the production of VR induced symptoms and effects was developed, with four main factor groups identified as; VR technical system, Virtual Environment (the content of the virtual "world") design, circumstances of use and individual participant characteristics [26]. Secondly, although the symptoms and effects identified were similar to those found with other simulators and in transportation, the causes and symptom patterns were considered to be sufficiently different to justify a new term: virtual reality induced symptoms and effects (VRISE) [6]. The term "cybersickness" has also been used to describe the sickness element of this symptom set. Thirdly, a wide variety of individual differences in susceptibility to, and experience of, effects was observed. From data obtained from over 200 participants, 80% of participants across all experiments reported some experience of VR induced symptoms. For most people these were mild and short-lived but 5% of participants experienced symptoms so severe that they had to end their period of VR exposure [6].

1.2. Projection based displays

One of the advantages of desktop viewing is that it allows several users to view a VE at the same time. Whilst two or three viewers may sit comfortably at a PC workstation, the potential for additional VE viewers may be facilitated by projecting the VE onto a larger screen using a standard PC-compatible projector. Such displays are commonly used for slide presentations and can be used to display a VE for viewing by a group or with which the participants can interact in real-time using the PC input devices, although some degradation in display quality is experienced. In addition, a number of higher resolution methods of displaying a VE in stereo or monoscopic modes are available. These technologies include CAVES, passive and active stereo systems with magnetic or infra red tracking and horizontally curved screen displays (sometimes termed "reality theatre). A curved display set-up typically consists of a room containing a 7.5 m diameter screen over 150° of arc across the room, and from floor-to-ceiling. Three colour projectors are used to display computer generated images on this screen, and an advanced audio sound system enhances the impression of immersion in the VE. Although these display systems require expensive computing resources they can be used to display VEs created on standard PC-based systems and therefore may be used for final presentation of designs, layouts or training to a group of users. These displays are not stereoscopic but do attempt to promote a sense of immersion (physical enclosure in the display, thought to be associated with a sense of presence) via the size of the display.

It is feasible to envisage that VE applications in the workplace may use standard PC displays for single users (e.g. in the development of product design, architecture, or training applications) and projection screen displays for meetings and presentations. This has been seen by the authors in a number of industrial contexts (including aerospace and automotive) over recent years as a useful tool for communicating rationale behind design decisions that have been made using virtual prototype models or for supporting the design decision making process.

Each of these different types of viewing conditions produce varying combinations of sensory input to the participant. In all of the conditions there is a basic difference between the information received by the visual system and the vestibular or non-vestibular proprioceptive system during movement around a VE, where the visual information indicates that the participant is moving, but the vestibular and proprioceptive informs the participant that they are stationary. Sensory conflict theory [29] uses this difference as the basis for the causative theory of motion sickness. This theory also states that where *unexpected* conflict occurs between sensory inputs, the participant is more likely to experience sickness. There are differences in the extent to which this conflict occurs, and the degree to which this conflict is expected, in different VE viewing conditions. For example, in the desktop viewing condition, the participant usually has control over their movement within the VE, whereas in a curved large screen display, the most likely scenario is that the movement around the VE is governed by an independent controller. The participants in the desktop viewing condition will have a higher degree of expectation about the direction in which they are likely to travel, and the interactions with the VE that might be performed. Therefore it is necessary to consider not only how participants' experiences of sickness differ in the different viewing conditions, but what the underlying differences between these conditions are, and therefore what might cause the differences in VRISE experienced. In addition, the lighting conditions in the viewing room may vary from light to dark, and this may affect the symptoms experienced by the participants. In this paper, both a general examination of the prevalence and severity of sickness in four display conditions, and a controlled examination of the role of two aspects of VE display conditions (active vs. passive viewing, light vs. dark viewing) are presented.

1.3. Effects of display types on VRISE

One of the main aims of this research project was to complete a controlled assessment of the influence of different VE display types on VRISE. This section of the literature review summarises previous work that has examined the effects of different display media.

1.3.1. Head mounted displays

The range of commercially available HMDs and the variety of conditions under which they are used (e.g. different virtual environments, users completing different tasks under different constraints and over differing time periods) make comparisons in symptom profiles between headsets difficult. The following section summarises the prevalence