Comparison of Desktop, Head Mounted Display, and Six Wall Fully Immersive Systems using a Stressful Task

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ABSTRACT

The goal of the current study was to investigate the effects of different virtual environment (VE) technologies on emotional arousal and task performance in a modified Stroop task presented under low- and high-stress conditions. Fifty-three participants were recruited from a college population. Reactivity to stressful VEs was examined in three representative VE systems from desktop to high-end fully immersive systems. The experiment was a 3 (desktop system, head mounted display (HMD), and six wall system) x 2 (high- and low-stressful VE) within subject design, with self-reported emotional arousal and valence, skin conductance, task performance, presence, and simulator sickness. Replicating previous studies, the fully immersive system induced the highest sense of presence and the HMD system elicited the highest amount of simulator sickness. Extending previous studies, the results showed that different technological platforms evoked unique response patterns. Our findings suggest that different VE systems may be appropriate for different scientific purposes when studying stress reactivity using emotionally evocative tasks.

KEYWORDS: Virtual Environments, Human Response, Stress, Emotion, Psychophysiology, and Behavior.

INDEX TERMS: J.4 [Computer Application]: Social and Behavioral Science-Psychology

1 INTRODUCTION

Over the past two decades, virtual environments (VEs) have been developed for use as a human-computer interaction platform across a wide variety of applications, including education, gaming, and the scientific study of complex human behavior [1]. Because VEs permit the scientific study of human behavioral responses in a controlled laboratory setting alongside ecologically valid contextual cues, this approach has the capability of enhancing both internally and externally valid experimental designs. As such, VEs can be valuable in the experimental investigation of neurobehavioral processes (e.g., emotion, attention, behavioral disinhibition) underlying psychiatric disorders. However, this area of research is still in an early phase of development, and many questions remain about how to optimize the use of VEs in the study of basic processes underlying psychiatric disorders.

One consideration is the selection of a technological platform to use for the presentation of VEs. Studies with VEs have utilized a range of technological platforms, such as: (1) a simple desktop personal computer (PC) with a standard monitor, (2) a desktop PC or laptop computer with a head mounted display system (HMD; i.e., goggles with limited peripheral vision), and (3) more immersive virtual environments where the participant stands or walks inside a room with a projected computer display across up to six walls, including floor and ceiling (i.e., cave automatic virtual environment (CAVE)). Although the choice of technological platform for any given experiment may be influenced by a number of pragmatic and logistical factors (e.g., cost, space, expertise available, etc.), scientific methods can be used to examine whether there are differential responses to these technological platforms.

Previous studies have begun to investigate this question. For example, researchers have evaluated projection-based dome, HMD, desktop, or CAVE systems for navigation tasks, such as way-finding tasks and path-finding tasks [2,3]. However, most previous studies investigating differential responses across VE platforms have been designed to address this issue in tasks involving spatial navigation or visualization. In contrast, considerably less is known about whether basic processes of emotional arousal and the regulation of emotions are differentially influenced by the type of VE technological platform.

In the present study, we examined the role of different VE technologies on performance both in high-stress and low-stress tasks, as well as on subjective and psychophysiological dependent measures of stress reactivity. Indeed, we examined emotional reactivity in three representative VE systems. The experiment was a 3 (CAVE, HMD and Desktop PC) x 2 (high-stress VE and low-stress VE) within subject design, with the primary dependent variables of psychophysiological, self-reported, and behavioral measures of stress reactivity.

Figure 1. Desktop (left); HMD (middle); and CAVE system (right)

2 METHOD

2.1 Virtual Environments

Six Wall CAVE. As a CAVE technology (Figure 1), we used the Duke immersive Virtual Environment (DiVE), a 3m x 3m x 3m fully immersive [4] system with stereoscopic rear projected room with head and hand tracking and real time computer graphics.

HMD System. The HMD (Figure 1) had a 40 degree field of view system with head and hand tracking and real time computer graphics. In addition, it had a stereographic view, and participants interacted with objects in the virtual kitchen through the use of wand (Intersense) and tracker (Intersense IS-900 tracking system).

Desktop PC. A standard PC (Figure 1) was also used. The VE was identical to that presented in the DiVE and HMD systems, but all advanced technical components were eliminated. it has a mono view, and participants interacted through a standard mouse.

VE Task. In this task, we used a modified 3D version of the Stroop task [5]. Participants were instructed to find two word cards (green and blue word cards) while ignoring the color of the words (i.e., a word spelled "RED" but colored blue). During the low-stressful task, the color of the word and the meaning of the word were congruent, whereas the two were incongruent in the

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high-stressful task (Figure 2). In addition, there was no aversive stimulation during the low-stress task, whereas participants were asked to complete the task with aversive stimulations during the high-stress task occurring in the VE. As aversive stimulations, we used loud noises, unexpected flashes, and tactile vibration.

Figure 2. Low-stressful task (left) and High-stressful task (right)

2.2 Dependent Measures

Self-report. After completing each task, participants were asked to complete the Self Assessment Manikin, Presence Questionnaire, and Simulator Sickness Questionnaire.

VE task performance. During the card finding task, participants were instructed to find two word cards, (*blue* and *green*), ignoring the color of the word. As a measure of task performance, we computed time to complete the card finding task in the low- and high-stress tasks in three different VE systems.

Skin Conductance. We also collected measures of galvanic skin response (GSR) as a measure of sympathetic autonomic arousal.

3 Result

3.1 Arousal, Valence, VE Performance, and Skin Conduction: New Findings

A 3 x 2 ANOVA was used to test for difference in self-reported emotional arousal and valence, total task time, and SCR among the three VE systems (DiVE, HMD, and desktop systems) across the two stress conditions (high- and low-stress condition). For arousal, there were significant main effects of the VE systems, $F(2,102) = 18.383$, $p < .001$, $\eta^2 = .27$. As shown in Fig. 3 (left), the DiVE and the HMD elicited higher emotional arousal than desktop system. For valence, there were significant main effects of the VE systems, $F(2,102) = 23.441$, $p < .001$, $\eta^2 = .32$. As shown in Fig. 3 (right), the DiVE elicited relatively positive emotional changes, but the HMD elicited negative emotional changes with comparing other VE platform. For total task time, there were significant main effects of the VE systems, $F(2,104) = 12.912$, $p < .001$, $\eta^2 = .20$. In addition, there was a significant interaction effect between VE systems and stress conditions, $F(2,104) = 3.776$, $p < .05$, $\eta^2 = .07$ (Fig. 4, left). For SCR, there were significant main effects on the VE systems, $F(2,100) = 7.581$, $p < .001$, $\eta^2 = .13$. As shown in Fig. 4 (right), the DiVE elicited the highest SCR changes, the HMD elicited moderated changes.

3.2 Presence and Simulator Sickness: Replication of previous findings

Presence differed significantly across the three VE systems, $F(2,104) = 85.774$, $p < .001$, $\eta^2 = .62$, and simulator sickness was also significantly different among the three systems, $F(2,100) = 25.195$, $p < .001$, $\eta^2 = .48$.

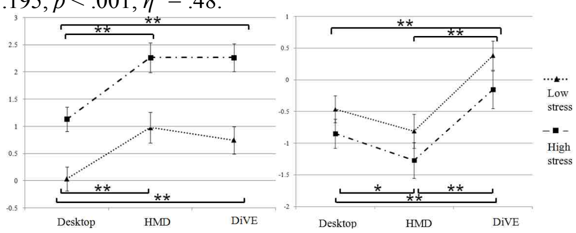

Figure 3. Arousal (left) and Valance (right)

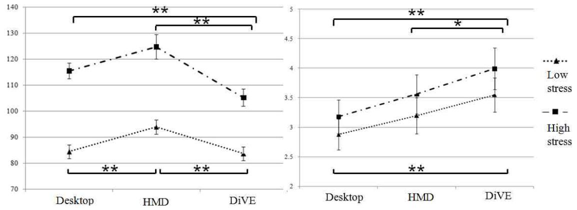

Figure 4. Task performance (left) and Skin conductance (right)

4 Discussion

This study provides important and unique findings about benefits and limitations of different VE systems for different purpose of human research. The six-wall CAVE system (i.e., DiVE) evoked the biggest positive emotion compared to HMD and desktop systems, while the HMD system evoked the largest negative emotion among the three systems. The desktop system resulted in the smallest emotional changes and moderate task performance. That is, the CAVE-like system can be useful to evoke happy and positive emotion, whereas the HMD-like system can be advantageous to evoke negative emotion. This finding is valuable and can be applied to plan and design experiments for psychotherapy research, which utilizes the human-computer interaction (HCI) or VE technologies. For example, CAVE-like systems may be useful for relaxation treatments, while HMD-like systems may be effective for treatments or assessments of anxiety disorders (i.e., phobia) in psychotherapy. As such, the findings from our study play an important role to answer questions about which technological approach is appropriate for certain psychotherapy. It is also worthwhile to note that each VE technology has different effects on human emotional responses despite the fact that we used the same task across the three different VE systems. Therefore, it is critical to consider the effects of technologies on the task performance on top of the research purpose when investigating human emotional behaviors with VE technologies.

The result of this study is important and informative because VEs have been increasingly used in the research of neurobehavioral responses in human, and still have infinite potential in human research. Our findings suggest that different VE systems are useful for different purposes of studies. With insightful follow-up studies, the results of this study can be widely used in research of human behaviors in both healthy and psychiatrically impaired populations.

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