A Comparative Investigation of Assessment of Brain Activities in Immersive Visualization Environments

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Abstract

The primary goal of this article is to comparatively investigate the assessment of brain activities in head- mounted and dome-shaped immersive visualization environments (IVE), consequently establishing a baseline for the effectiveness of objective assessment for immersive environments. Twelve college students were chosen at random to participate in the study. The investigation made use of electroencephalography (EEG) to measure the brain waves of the subjects with no outside stimuli. The researchers measured the activities of the subjects' brainwaves using EEG in two different IVE systems. Two experiments were conducted in four sessions of five minutes each for two distinctly configured IVE systems. The preliminary analysis of collected data indicated that dome- shaped IVE system performed better than head-mounted IVE system. In most cases, subjects had a decline in activities of brain waves from baseline brain activities under the influence of an immersive relaxation scene. In rare instances, there were some subjects that showed extreme increases in brain activities. Since this is an extremely small sample, future study is under way to investigate a larger number of subjects and determine whether dome-shaped environment continue to show higher performance over head-mounted environment.

Introduction

The majority of research into the effects and applications of immersive visualization environments (IVE) has utilized subjective measurements. There remains a strong need to include objective measures in order to improve validation of the effectiveness of IVE. In a recent study by the authors of this work, a comparative investigation into the sense of presence of traditional virtual reality (i.e. head-mounted system) and immersive environments (i.e. dome-shaped system) was conducted and reported in detail [1]. The subjective measurements in this study showed that participants experienced a higher sense of presence in immersive visualization environment when compared with the traditional virtual reality environment, indicating significantly more natural and richer subjective experience through the IVE system's interface. Furthermore, this investigation directly relates and contributes to the authors' main thrust of research in virtual reality therapy (VRT) combating phobias and other psychological disorders [2, 3, 4]. Therefore, in line with this investigation, the effectiveness of each IVE system is evaluated by measuring the reduction of brain activities (toward a meditative state). The lower the brain activities waves, the more relaxed the subject feels in the environment, and thus the more effective the sense of presence. To this end, authors briefly explain phobia, VRT, and brainwaves in the following sections.

It is reasonable to state that some type of phobia is reported in most people to some extent today. These phobias range from manageable to extreme and in most cases cause only mild discomfort. However, some experience more severe and often uncontrollable fears that must be treated. The most common form of treatment is the confrontation of these fears in some form, either by imagination or in real-life situations [8]. Using environments for treatment that the subject is comfortable with, particularly in an uncomfortable situation, is often difficult [5, 6, 7].

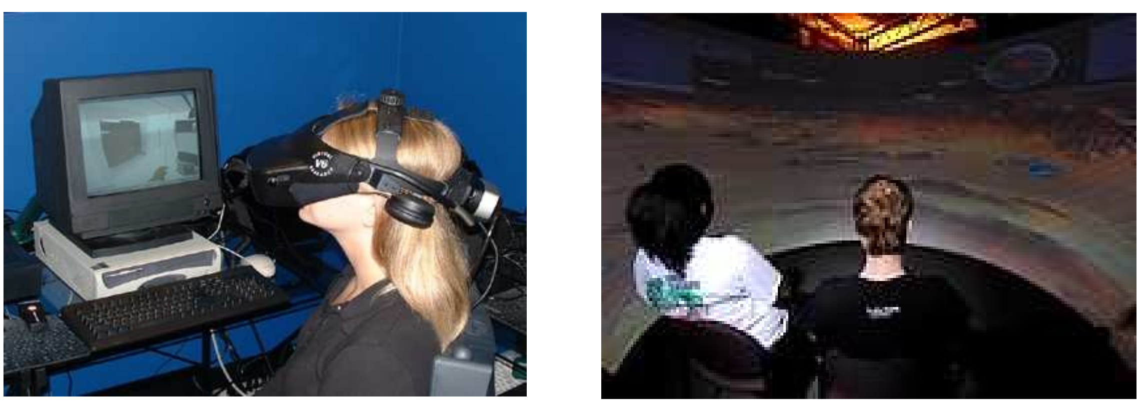
For the past two decades, virtual reality therapy has shown to be an effective treatment for phobias and other psychological disorders [2, 3, 4]. As a matter of fact, authors of this article have conducted pioneering research in VRT for a variety of psychological conditions [6]. In addition to subjective measures that have been used in the past, electroencephalography (EEG) offers the ability to objectively measure success in treatment [9, 10]. The establishment of a baseline reading and subsequent reading of subjects experiencing true phobias will determine the effectiveness of virtual reality therapy on those experiencing problems in this area.

The communication of neurons in the brain produces brainwaves (a product of electrical pulses from the neurons), and these brainwaves can be detected easily and recorded by devices such as an EEG [11]. The brainwaves alter based on subject activities, thoughts and feelings. In general, slower brainwaves are produced when subject is inactive. Higher frequencies of brainwaves are related to the period in which a subject is highly alert. Brainwaves are measured in Hertz (cycles per second), and they are roughly categorized as slow (Theta waves – 3 to 8 Hz), moderate (Alpha waves – 8 to 12 Hz) and fast waves (Beta waves – 12 to 38 Hz). A simplified explanation of these waves would be that (i) Theta brainwaves occur in sleep and deep meditation, (ii) Alpha brainwaves happen while quietly thinking and in meditative situations, and (iii) Beta brainwaves arise in a waking state of consciousness [11].

The primary goal of this article is to comparatively investigate the assessment of brain activities in head-mounted and dome-shaped immersive visualization environments, consequently establishing a baseline for the effectiveness of objective assessment for immersive environments. Furthermore, since the effects of VRT on subjects treated for neurosis have traditionally been evaluated through subjective measurements, there is a need to include objective measures. This will improve and validate the effectiveness of VRT as well as showing which IVE is more effective for treatment.

Methodology

In this preliminary investigation, twelve (12) college students were chosen at random to participate in the experiments. There was no preference in selecting subjects regarding gender, age, race, or any other characteristic. The experiments incorporated an EEG hardware and software to measure the brain waves of the subjects with no outside stimuli. Two experiments were conducted in four sessions for five minutes per session on each of two IVE systems (head-mounted and dome-shaped). All sessions were conducted in one sitting. Subjects who participated in experiments were selected when they showed no visible or admitable signs of fear of the simulated environments. Specifically, we measured the activities of the brainwaves in response to a virtual relaxation scene using EEG technology under two differently configured and generated IVE systems (Figure 1). Prior to the main phase of the experiments, with no IVE equipment connected to the subject, a baseline of brain activities was established. Then other sessions were conducted, and EEG signals (Alpha, Beta and Theta bands) were recorded while under each immersive environment experience. Four sessions were conducted consecutively in five minutes intervals and data were collected accordingly.



(a) **(b)**

Figure 1. Illustrates (a) A Head-mounted configured IVE system; and **(b)** A Dome-shaped configured IVE system

Preliminary Results

The preliminary data indicated that in most cases, subjects had a decline in activities of brain waves compared with baseline brain activities when under influence of an immersive scene. In rare instances, there were some subjects that showed extreme increases in brain activities. In all but one case, subjects were actually more relaxed while under either IVE system than baseline. Details of the data collected are represented in Tables 1, 2, and 3. In addition, merely considering the data, it seems that the overall mean of all three brainwaves (Alpha, Beta and Theta) for subjects within a dome-shaped IVE were lower than that measured during head-mounted experiments, supporting the assertion that dome-shaped IVE provided a more relaxed state than its counterpart. However, the statistical analysis of data using t-test showed statistically no significant difference between collected EEG data from all twelve subjects using head-mounted and dome-shaped systems (Table 4).

Table 1. Experiments - IVE Head-Mounted and IVE Dome-Shaped - Alpha 8 - 13 Hz

IVE Head-Mounted - Alpha 8 - 13 Hz				IVE Dome-Shaped - Alpha 8 - 13 Hz			
Min.	**Peak**	**Mean**	**Std. Dev**	**Min.**	**Peak**	**Mean**	**Std. Dev**
1.56	79.15	13.76	12.7	0.92	75.81	7.92	7.34
2.11	189.26	25.67	23.1	1.56	139.2	9.34	8.09
0.97	29.91	5.87	3.25	0.68	34.86	5.19	3.78
0.96	75.45	5.92	4.76	1.02	26.56	5.48	4.21
0.49	24.51	6.02	3.89	0.57	42.04	5.01	4.04
2.03	55.63	8.99	6.12	0.99	32.87	6.34	4.38
1.29	69.05	8.74	6.98	1.52	37.1	7.83	3.41
0.68	75.44	8.92	5.89	0.42	40.89	6.22	5.89
0.78	44.81	6.9	6.14	0.49	42.63	6.87	7.02
1.48	45.16	8.78	6.38	0.31	37.38	6.27	6.12
0.87	64.77	5.24	5.01	0.68	67.32	5.91	4.45
0.82	18.98	5.02	2.77	0.83	17.34	5.58	3.21

Table 2. Experiments - IVE Head-Mounted and IVE Dome-Shaped - Beta 15 - 20 Hz

IVE Head-Mounted - Beta 15 - 20 Hz				IVE Dome-Shaped - Beta 15 -20 Hz			
Min.	**Peak**	**Mean**	**Std. Dev**	**Min.**	**Peak**	**Mean**	**Std. Dev**
1.17	108.81	7.83	9.26	0.88	119.14	8	12.12
2.05	135.7	15.46	10.89	0.88	101.02	5.37	5.31
1.27	18.22	5.85	2.7	1.46	21.72	7.21	2.98
0.49	53.19	2.91	2.97	0.58	21.72	3.6	2.44
0.68	45.79	4.46	3.07	0.58	21.82	3.9	2.85
1.46	59.33	7.74	5.87	0.88	33.32	5.08	3.09
1.17	47.83	6.61	3.91	0.78	21.14	4.8	2.58
0.58	80.47	4.67	3.65	0.68	13.83	3.42	1.78
0.78	45.2	4.6	3.29	0.68	36.04	4.09	2.83
0.88	40.43	5.41	4.26	0.97	29.81	5.14	3.87
0.49	51.92	3.91	4.15	0.49	42.08	2.67	2.45
0.68	9.06	2.55	1.07	0.49	10.23	2.55	1.22

Table 3. Experiments - IVE Head-Mounted and IVE Dome-Shaped - Theta 4 - 8 Hz

IVE Head-Mounted - Theta 4 - 8 Hz				IVE Dome-Shaped - Theta 4 - 8 Hz			
Min.	Peak	Mean	Std. Dev	Min.	Peak	Mean	Std. Dev
1.95	571.15	39.05	49.14	1.46	82.71	11.66	9.79
6.92	573.1	157.08	107.2	6.43	467.01	124.97	86.78
0.49	113.98	9.79	16.93	0.58	109.98	8.25	15.5
1.07	85.14	13.94	15.16	1.07	75.01	11.13	9.82
0.88	206.72	13.33	15.75	0.88	102.48	7.96	9.46
1.46	286.4	41.36	42.16	0.58	63.13	7.23	8.34
2.44	463.5	81.16	72.65	0.68	207.59	27.9	26.07
0.88	172.23	26.97	27.29	0.88	128.78	22.29	26.66
0.88	104.72	13.38	11.03	0.49	149.14	18.15	23.48
0.78	269.55	41.52	37.42	1.27	121.28	14.25	15
0.39	196.1	12.02	15.07	0.58	63.71	8.01	8.75
0.97	124.5	24.13	17.65	0.88	60.5	8.31	8.24

Table 4. Depicts Mean and Standard Deviation for both IVE systems and statistical analysis for all three brainwaves using t-test.

Brainwaves (Selected)	IVE Head-Mounted		IVE Dome-Shaped		Analysis		
	Mean	Std. Dev	Mean	Std. Dev	t-value	p-value	Significant
Alpha 8 - 13 Hz	9.1525	5.7441	6.4967	1.2904	1.5627	0.1324	Negative
Beta 15 - 20 Hz	6.0000	3.2727	4.6525	1.6669	1.2274	0.2326	Negative
Theta 4 - 8 Hz	39.4775	42.2330	22.5092	32.9214	1.0977	0.2842	Negative

Conclusions and Discussions (Concise)

The analysis of collected data indicated that in most cases, subjects are more relaxed while under any IVE system. While the overall mean of IVE dome-shaped systems was lower than the overall mean of IVE head-mounted systems, the t-test showed statistically no significant difference between systems in inducing relaxation in subjects. There are two possible unsophisticated reasons for the outcome of this analysis; (i) the small sample size of twelve, and (ii) large standard deviations. It must be noted that despite the overall result of statistically no significant differences between the systems, some of individual subjects showed dome-shaped IVE experiments to be significantly different from head-mounted IVE experiments, while the others showed the reverse results. Logically, since this was a small sampling, future investigation is under way to investigate larger groups and to determine what causes this difference in the current subject population. Furthermore, it must be reiterated that this investigation is at its preliminary stage, with an extremely limited number of subjects participating, and thus the results and conclusions are also preliminary. Therefore, authors intentionally are limiting their current interpretation of results and conclusions at this time until further extensive experimentation is conducted and a larger collection of data becomes available.

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