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Presence and Emotions in Virtual Environments: The Influence of Stereoscopy

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ABSTRACT

This study investigates how stereoscopy (the illusion of depth and 3D imaging) affects the sense of presence and the intensity of the positive mood that users feel in virtual environments (VEs). A between-group design was used, and 40 volunteers were randomly assigned to one of two experimental conditions (stereoscopy vs. no stereoscopy) and to one of two emotional VEs (relaxation or joy). The participants' emotions were assessed before and after the VR experience. Presence was measured with two postexperiment questionnaires (ITC-SOPI and SUS). Results show that there were no differences between stereoscopic and monoscopic presentations in VEs (neither subjective sense of presence nor emotional reactions). Practical and theoretical implications of these findings are discussed herein.

INTRODUCTION

The notion of "being present" in the virtual world has been considered central to virtual environment (VE) endeavors since the technology was first created. Presence is traditionally considered the psychological sense of "being in" or "existing in" the VE in which one is immersed. Beyond this simple definition, what exactly presence is and what causes it remains somewhat of a mystery. To date, there are several definitions and theories on its nature that do not necessarily contradict each other, although they can have different implications.

To better understand this concept, one must understand the different types of presence that can be elicited in a VE. IJsselsteijn et al.[1] distinguished between *social presence* (the feeling of being together and communicating with others) and *physical presence* (the feeling of being physically located in a place). Similarly, Heeter[2] distinguished between three different types of presence: *personal presence* (the extent to which the person feels physically present in the VE), *social presence* (the extent to which other beings, living or synthetic, also exist in the VE), and *environmental presence* (the extent to which the environment itself recognizes and reacts to the person in the VE). This work is focused on personal (physical) presence.

Beyond these distinctions, most researchers also acknowledge that the sense of presence is a complex and likely multidimensional construct.[1,3,4,5] In this line, Kalawsky[6] cautions that "presence is a multidimensional parameter that is arguably an umbrella term for many interrelated perceptual and psychological factors."[6(p5)] In fact, most theories attempt to explain presence in terms of several underlying factors that could be classified in two general categories of variables: *user characteristics* and

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media characteristics.[1,7,8] User characteristics refer to the range of individual differences (age; gender; the user's perceptual, cognitive, or motor abilities; personality characteristics, etc.). The characteristics of the medium have been divided into *media content* and *media form* variables.[9] Media content variables are the objects, actors, and events represented by the medium and include variables such as story and plots, identification/empathy with the characters, social interaction, emotion, and preknowledge. Several studies have linked these "nontechnological" elements to presence. Media form variables include the properties of the display medium and are aimed at making the medium as transparent as possible. There are also many studies that have identified formal (technological) factors that contribute to enhancing the user's sense of presence; many of them are spatial or perceptual cues such as providing a wide field of view display, head tracking, stereoscopy, 3D sound, propioception, maps/landmarks, and spatial interaction.

In a previous study,[10] we tested the role of a formal variable (immersion) on the sense of presence. Three immersive systems were used (a PC monitor, a rear-projected video wall, and a head-mounted display); results indicated that although immersion had an impact on presence, this role was more relevant for nonemotional VEs than for emotional ones. In the study, we concluded that presence is not a direct function of immersion alone, and a one-to-one relationship cannot be assumed to exist between immersion and presence.

In the present work, we analyze the role of another media variable related to immersion: stereoscopy. Stereoscopy is a technique for creating the illusion of depth and 3D imaging while presenting a different image to each eye. It was expected that this technique would enhance the sense of presence. Several previous studies have focused on this variable; all of them found that the use of stereoscopic presentation increased presence ratings. In the first one, Hendrix and Barfield[11] found significant effects for stereoscopy in a study with a within-subject design. Subjects participated in three consecutive experiments in which one of three variables was manipulated: stereoscopy, head tracking, and geometric field of view (the view-angle represented on the screen) of 10°, 50°, or 90°. Presence was measured using a two-item questionnaire. Results showed that the reported levels of presence were significantly higher when head tracking and stereoscopic cues were added and when wider fields of view were presented (50° and 90°).

Freeman and IJsselsteijn conducted a study analyzing the role of stereoscopy, image motion, and screen size on the sense of presence using subjective and objective measures of presence. In the first two works,[12,13] they found that participants experienced higher subjective levels of presence in scenes of a film that were presented stereoscopically. However, in these experiments, the presentation of stereoscopic and monoscopic sections of the film was not randomly varied. In a later study, Freeman et al.[14] adapted methods of continuous assessment of TV picture quality to assessing presence. While viewing a VE, subjects could manipulate a handheld slider indicating their sense of presence. The study manipulated stereoscopic and motion parallax cues within video sequences (containing monoscopic and stereoscopic segments). The results showed that the presentation of both stereoscopic and motion-parallax cues was associated with higher presence ratings.

In a more recent study,[15] participants in a within-subject design were exposed to four conditions based on two variables: stereoscopy and moving or still images. Results showed that stereoscopy had a positive effect on the magnitude of the participant's automatic postural responses (which were measured via a magnetic tracking device). Posttest subjective ratings of presence, vection, and involvement were also higher for the stimuli presented stereoscopically. Authors concluded that increasing the realism of a moving display by adding stereoscopic information increased both postural responses to the display and subjective ratings of presence. Finally, IJsselsteijn et al.[16] employed a large projection display with a 50° horizontal field of view and manipulated image motion and stereoscopic presentation in a within-subjects factor and screen size in a between-subjects factor. Results demonstrated a positive effect of stereoscopic presentation on the lateral postural responses and on posttest subjective ratings of presence.

All of these studies employed within-group experimental designs wherein participants experienced various stimuli and were asked to rate their sense of presence corresponding to each. Although these experimental designs are adequate for studies involving involuntary responses, they are less useful for subjective and voluntary responses because participants' responses can be influenced by stimuli previously used in the experiment.

Furthermore, all of these studies used nonemotional VEs (e.g., car rally scenes). In recent years, our research team has been investigating the role of emotions and mood on the sense of presence. The results of several studies have shown that VEs can be used as effective mood-induction procedures and that presence felt in emotional VEs is influenced not

only by formal factors but also by content (nontechnological) factors.[17,18] The present study continues this line of research and investigates the influence of stereoscopy on presence and the intensity of mood induction in VEs using a between-group design. This understanding is necessary for determining certain aspects of the system, including the context in which it is used, that contribute to effective and efficient VR applications.

Taking into account the above-mentioned studies, our hypotheses were (a) the sense of presence reported by participants will be greater in the stereoscopic presentation than in the nonstereoscopic presentation; and (b) stereoscopy will not influence the intensity of mood induction in a VE, and therefore mood changes will not be greater in the stereoscopic presentation than in the nonstereoscopic presentation.

MATERIALS AND METHODS

Participants

The sample consisted of 40 undergraduate and graduate student volunteers (13 men and 27 women) whose ages ranged from 18 to 40 years ($X = 23.7$, $SD = 5.13$). None of them was suffering from any medical or psychological disorders. Participants were randomly allocated to the two experimental conditions (stereoscopy and monoscopy) and the two emotional conditions (relaxation and joy). The four groups comprised 10 subjects.

Virtual environments

The VEs consisted of a neutral environment (a park) that changed progressively depending on the mood state (relaxation or joy) to be evoked in the user. In order to build these two different emotional environments, variations of each of the following elements were included: music (joy condition: "Eine Kleine Nachtmusik" by W. A. Mozart; relaxation condition: "Heavenly Theme" by Michael Lindh [from Interactive Institute, "Heavenly Theme" was validated as a neutral MIP in EMMA project]); Velten self-statements (an MIP developed by Velten,[20] wherein mood induction is achieved by means of statements written in first person, relative to the mood; subjects are asked to read the statements and to try to feel a mood similar to the one described in them);[19] pictures;[20] movies (for joy: scenes from *Singin' in the Rain*; for relaxation: scenes from *Out of Africa*); and autobiographical recalls.[10,17,18]

The VE's content was as follows: a woman's voice guides users through a virtual walk. Participants listen to a short history corresponding to the emotional experimental condition (joy or relax). The initial appearance of the environment is the same for all users but changes shortly thereafter depending on the intended emotional condition. From the beginning, a piece of music is heard. Participants have 2 minutes to freely explore the park. Then they are asked to go to a bandstand that is located in the center of the park. On each of the five sides of the stand, a statement of the Velten[19] technique appears (the content of the statements depends on the emotional condition). For each of the five sentences, participants must choose a picture[20] from four options which they feel best represents the meaning of the sentence. Participants are asked to contemplate the content of each sentence for 45 seconds and to think about the personal meaning of each statement. After that, they can walk around the virtual park again for 2 minutes. Then participants are asked to go to the cinema to watch a short film. When it is finished, they are instructed to produce an autobiographical recall similar to the experiences they encountered in the park.

Hardware

The workstations for running the VEs were PC computers with high-end graphics capabilities, including 128Mb memory for graphics and textures. The interaction device was a wireless pad with two small joysticks, one used to navigate and the other to interact. The immersion display consisted of a metacrilate screen of 400 × 150 cm and two projectors (1024 × 768 pixels). Participants viewed the VE wearing polarized glasses.

Measures

Two kinds of measures were employed in the experiment: emotion measures (before and after VEs) and presence measures (after VEs).

Visual analogue scale (VAS). In order to assess emotional reactions, four VASs were used. A variation of the original measure[21] was used. Participants were asked to rate on a 0- to 10-point Likert Scale (0, not feeling the emotion at all; 10, feeling the emotion very strongly) how they felt at that moment in each of the following emotions: sadness, joy, anxiety, and relaxation.

Positive Affect Negative Affect Schedule (PANAS).[22] The PANAS is a list of 20 adjectives used to describe different feelings and emotions: 10 positive moods/emotions and 10 negative moods/emotions. Participants must indicate if they feel these emotions in that moment with a 1- to 5-point scale (1, very slightly or not at all; 5, very strongly).

ITC-Sense of Presence Inventory (ITC-SOPI).[23] The ITC-SOPI is a posttest subjective presence measure composed of 44 items divided in two parts. Part A (6 items) refers to a respondent's impressions/feelings *after* a media experience has finished. Part B (38 items) refers to a respondent's impressions/feelings *during* a media experience. A 1- to 5-point Likert scale (from strongly disagree to strongly agree) is used for responding to both parts. Factor analysis showed that this questionnaire measures four dimensions: physical space, engagement, ecological validity, and negative effects. Internal reliability coefficients (alpha) were computed for each of the four factors. Alphas were high, ranging from 0.94 (physical space) to 0.76 (naturalness).

SUS presence questionnaire.[24] This is a post-hoc questionnaire that consists of six questions, all of which were variations on one of three themes: the sense of being in the VE, the extent to which the VE becomes the dominant reality, and the extent to which the VE is remembered as a "place." Each was rated on a 1 to 7 scale, and the presence score was taken as the number of high scores (6 or 7).

Procedure

All participants were tested individually. Participants were provided informed consent to take part in the study and were asked to complete a short screening interview in order to determine exclusion criteria. Next, they were randomly assigned to one of the four experimental conditions. The experimental session began with participants completing the pre-induction emotion measures. Then, in a brief training session with an experimenter, each participant practiced moving and interacting with virtual objects. Next, participants were left alone in the room, and the virtual session started; it took 30 minutes to complete the virtual walk. Finally, participants completed the emotion and presence questions. All participants were debriefed following the experiment.

RESULTS

Table 1 presents means and standard deviation for the emotion questionnaires; Table 2 lists presence data.

First, analyses of variance (ANOVAs) for the emotional measures at pretest were applied. Results showed insignificant differences between the various conditions for all measures, indicating that participants did not differ at baseline.

In order to determine if there were differences in the efficacy of the VEs to induce joy and relaxation using stereoscopy and monoscopy, VAS and PANAS measures before and after the induction were compared. Emotion measures (four VAS measures, PANAS-positive and PANAS-negative) were entered into a 2 (stereoscopy vs. monoscopy) $\times$ 2 (joy vs. relaxation) between-subjects $\times$ 2 (time: before vs. after) within-subjects ANOVA. In all six ANOVAs, only the main effect for time was statistically significant (see Table 3). Participants self-reported an increase in positive emotions (joy, relaxation, PANAS-positive) and a decrease in negative

Table 1. Means and Standard Deviations for Emotion Measurements

		Joy group				*Relaxation group*			
		Mono		*Stereo*		*Mono*		*Stereo*	
Measures	*Time*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
VAS joy	pre	4.7	0.32	5.0	0.32	4.7	0.32	5.1	0.32
	post	5.3	0.28	5.3	0.28	5.0	0.28	5.2	0.28
VAS sadness	pre	2.6	0.39	2.1	0.39	2.4	0.39	2.1	0.39
	post	1.7	0.27	1.5	0.27	1.7	0.27	1.7	0.27
VAS anxiety	pre	2.6	0.50	2.0	0.50	2.4	0.50	2.6	0.50
	post	1.4	0.21	1.2	0.21	1.3	0.21	1.4	0.21
VAS relax	pre	4.6	0.38	5.1	0.38	4.6	0.38	4.5	0.38
	post	5.5	0.23	5.8	0.23	5.9	0.23	5.2	0.23
PANAS-positive	pre	29.5	2.03	29.6	2.03	29.1	2.03	33.6	2.03
	post	31.8	2.40	31.7	2.40	30.6	2.40	34.1	2.40
PANAS-negative	pre	14.5	1.51	12.3	1.51	15.3	1.51	13.7	1.51
	post	8.1	2.03	8.9	2.03	8.7	2.03	9.9	2.03

VAS, visual analogue scale; PANAS, positive affect negative affect schedule; SD, standard deviation.

TABLE 2. MEANS AND STANDARD DEVIATIONS FOR PRESENCE MEASUREMENTS

	Joy group				*Relaxation group*			
	Mono		*Stereo*		*Mono*		*Stereo*	
Measures	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
ITC-negative effects	11.5	4.67	12.2	6.39	10.6	6.50	12.0	4.64
ITC-engagement	44.1	5.70	42.5	7.20	44.6	8.55	42.5	11.78
ITC-naturalness	17.0	4.21	15.9	2.28	16.7	3.91	18.3	4.19
ITC-spatial presence	61.0	11.26	54.9	9.70	63.0	7.37	64.6	14.42
SUS	2.0	2.16	1.8	2.20	2.1	1.59	1.4	1.95

ITC, sense of presence inventory; SUS, SUS presence questionnaire; SD, standard deviation.

emotions (sadness, anxiety, PANAS-negative). These results suggest that both VEs were effective for inducing positive moods. No differences were found between stereo and nonstereo groups, and no interaction effect was found.

Regarding presence measures, ITC factors and SUS measures were entered into a 2 (stereoscopy vs. monoscopy) $\times$ 2 (joy vs. relaxation) between-subjects ANOVA (see Table 4). Results showed no differences between joy versus relaxation groups and stereoscopy versus monoscopy groups in any of the four ITC factors (physical space, engagement, ecological validity, and negative effects). Likewise, no differences were found with the SUS questionnaire.

In order to further study the relationship between presence and emotional responses, correlational analyses were performed across presence variables and postinduction emotional variables (see Table 5). All presence measurements (except negative effects from ITC) correlated to positive emotion VAS (joy and relaxation) and PANAS (positive and negative).

DISCUSSION

The goal of this study was to test the role of stereoscopy in the sense of presence and mood intensity in VEs. Results indicate that there are no differences between stereoscopic and monoscopic presentations for both presence and emotion measures.

Regarding presence, the results do not replicate previous findings[11–16] showing that subjective feelings of presence are enhanced by stereoscopic stimuli presentation. The major difference between previous and studies and the current one is the content of the VEs. Our VEs are designed specially for inducing positive moods, whereas previous works employed neutral VEs. It may be that for this specific purpose, stereoscopic presentation is not as critical and technological factors are more relevant for nonemotional environments than for emotional ones.

Regarding the second area of inquiry, data support the hypothesis that stereoscopy does not affect the intensity of mood induction. That is, similar emotional reactions are elicited by both monoscopic and stereoscopic presentations. Furthermore, present results replicate previous findings[10,18] that indicate the subjective sense of presence is related to emotional reactions. Participants who experienced a strong feeling of presence also reported stronger positive emotional reactions. These findings are consistent with those obtained by Västfjäll[25] using music with an emotional tone to induce emotional reactions. However, in both our study and Västfjäll's paper, data are correlational and therefore do not support any causal explanation. There are several possible explanations for this relationship. It could be that emotion is a prerequisite for experiencing presence[26] or that emotion is determined by presence. Frijda[27] argues the latter point, suggesting that emotions arise when events are appraised as real, and their intensity corresponds to the degree to which this is the case. The present study cannot determine the exact relationship between both concepts.

We must also emphasize the caveats of this study. First, the size of the experimental sample was limited. Second, we measured the sense of presence and emotional states using self-report questionnaires only. The subjective measures used are validated and effectively tested in different contexts, but the inclusion of physiological and other objective measures may help in obtaining a more complete picture in future studies.

Nevertheless, these results have practical and theoretical implications for VR design. Practically speaking, emotional responses can be enhanced by the use of less realistic and sophisticated technology. Therefore, employing expensive VR devices can be superfluous if the purpose is to induce emotions in participants. Developments in VR therapy systems could benefit from taking this into account.

Table 3. ANOVAs Results for Emotion Measurements

	Moment		*Emotion (joy vs. relaxation)*		*Presentation (stereo vs. mono)*		*Emotion × presentation*		*Time × emotion*		*Time × presentation*		*Time × emotion × presentation*	
	f	*p<*	*f*	*Sig.*	*f*	*p<*	*f*	*p<*	*f*	*p<*	*f*	*Sig.*	*f*	*Sig.*
VAS-joy	5.156	0.029	0.078	ns	0.763	ns	0.031	ns	0.763	ns	0.078	ns	0.699	ns
VAS-sadness	11.745	0.002	0.125	ns	0.625	ns	0.000	ns	0.278	ns	0.000	ns	0.783	ns
VAS-anxiety	27.874	0.000	0.682	ns	0.136	ns	0.377	ns	0.136	ns	0.141	ns	0.141	ns
VAS-relax	21.130	0.000	2.441	ns	1.043	ns	0.261	ns	0.261	ns	0.610	ns	0.000	ns
PANAS-positive	4.336	0.056	1.029	ns	1.578	ns	0.037	ns	0.336	ns	0.371	ns	0.257	ns
PANAS-negative	25.105	0.000	0.028	ns	2.070	ns	0.002	ns	0.022	ns	0.408	ns	0.092	ns

VAS, visual analogue scale; PANAS, positive affect negative affect schedule.

Table 4. ANOVAs Results for Presence Measurements

	Presentation (stereo vs. mono)		*Emotion (joy vs. relaxation)*		*Presentation × emotion*	
	f	*Sig.*	*f*	*Sig.*	*f*	*Sig.*
ITC-negative effects	0.349	ns	0.096	ns	0.039	ns
ITC-engagement	0.462	ns	0.008	ns	0.008	ns
ITC-naturalness	0.045	ns	0.789	ns	1.304	ns
ITC-spatial presence	0.419	ns	2.831	ns	1.226	ns
SUS	0.510	ns	0.057	ns	0.157	ns

ITC, sense of presence inventory; SUS, SUS presence questionnaire.

Regarding theoretical implications, a fundamental research goal is to understand how presence is influenced by user and media characteristics. As Heeter[2] said, "The alchemy of presence in VR is in part a science of tradeoffs." Similarly, Ellis[28] has argued that an equation relating presence to its contributing factors must be such that iso-presence equivalence classes can be established, thus allowing an understanding of how different configurations and combinations of these factors can be used to attain a given level of presence. This is an important engineering requirement, allowing trade-offs between various system components.

This study supports studies that proved that the sense of presence is dependent not only on the quality of the sensory environment presented to the subject but also on the contents of the mediated communication and on the individual's characteristics. VR designers can influence only the two first factors: the sensory environment and the content. Therefore, their efforts should be directed toward producing high-quality sensory data and toward good, convincing storytelling. However, they should understand that if the content is of high quality, then even simple technology will be effective.[29] In some cases, it may not be necessary to employ expensive resources for perfecting technical details. As Heeter[30] says, "Sensory realism is certainly an important influence on presence, but there is more to the story."[30(p335)]. The author adds, "Even when technology is involved, it is the experience itself (the mediated experience) and not technology alone that engages the subjective experience of presence."[(p344)]

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Table 5. Correlations between Presence and Emotion Measurements

	Post-PANAS-negative	*Post-PANAS-positive*	*Post-VAS joy*	*Post-VAS anxiety*	*Post-VAS relax*	*Post-VAS sadness*
ITC-negative effects	0.216	0.191	0.051	0.082	0.138	0.277
	ns	ns	ns	ns	ns	ns
ITC-engagement	0.400	0.411	0.525	0.129	0.363	0.159
	0.011	0.008	0.001	ns	0.021	ns
ITC-naturalness	0.253	0.487	0.457	0.261	0.478	0.194
	ns	0.001	0.003	ns	0.002	ns
ITC-spatial presence	0.479	0.342	0.329	0.072	0.306	0.080
	0.002	0.031	0.038	ns	0.055	ns
SUS	0.367	0.361	0.472	0.026	0.396	0.007
	0.020	0.022	0.002	ns	0.012	ns

ITC, sense of presence inventory; SUS, SUS presence questionnaire; PANAS, positive affect negative affect schedule; VAS, visual analogue scale.

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