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Could you relax in an artistic co-creative virtual reality experience?

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Abstract

Our work contributes to the design and study of artistic collaborative virtual environments through the presentation of immersive and interactive digital artwork installation and the evaluation of the impact of the experience on visitor's emotional state. The experience is centered on a dance performance, involves collaborative spectators who are engaged to the experience through full-body movements, and is structured in three times, a time of relaxation and discovery of the universe, a time of co-creation and a time of co-active contemplation.
The collaborative artwork "Creative Harmony", was designed within a multidisciplinary team of artists, researchers and computer scientists from different laboratories. The aesthetic of the artistic environment is inspired by the German Romantism painting from 19th century. In order to foster co-presence, each participant of the experience is associated to an avatar that aims to represent both its body and movements. The music is an original composition designed to develop a peaceful and meditative ambiance to the universe of "Creative Harmony".
The evaluation of the impact on visitor's mood is based on "Brief Mood Introspection Scale" (BMIS), a standard tool widely used in psychological and medical context. We also present an assessment of the experience through the analysis of questionnaires filled by the visitors. We observed a positive increase in the Positive-Tired indicator and a decrease in the Negative-Relaxed indicator, demonstrating the relaxing capabilities of the immersive virtual environment.

CCS Concepts
• Applied computing → Performing arts; • Computing methodologies → Virtual reality;

1. Introduction

We propose to explore the impact of an artistic collaborative virtual environment on spectator's mood. In that purpose, we introduce a relaxing artistic artwork of co-creation, named "Creative Harmony", its intention, design and implementation.The experience involves a dance performer, and collaborative spectators who are engaged to the experience of co-creation through full-body movements. We detail an evaluation of its effect on the emotional state of its users, based on a standard psychological method, together with an assessment of the collaboration, curiosity of creation, involvement of the spectator in the interactive process and contemplation of the resulting virtual environment.

The collaborative artwork "Creative Harmony" was designed within a multidisciplinary team of artists and computer scientists. Collaboration is achieved at different levels. The first level of collaboration is related to the co-presence of users who share the same virtual space at the same time. The second level relies on a co-creative phase of a live virtual artwork between a performer and the spectators all connected in real-time to the collaborative environment of "Creative Harmony". The last level corresponds to the access to an emotional state of letting go experienced by the spectators engaged in a shared session.

First, we will present the context of our approach within the domain of digital art in virtual reality. Then, we will detail creation step of Creative Harmony, its design and implementation. Finally, we will present the method followed to assess the effet of the Creative Harmony experience on the emotional state of spectators and discuss the results we obtained, before concluding.

A video presentation of the Creative Harmony experience can be viewed at https://youtu.be/X8QdF8FmFv8.

2. Background

This section presents the challenges of virtual reality from an artistic and scientific point of view. The collaboration that it induces raises questions of co-presence, avatars and communication. In the same way, the perception of its environment creates emotions for the spectator, which can go as far as a state of letting go.

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2.1. Digital art in VR

Using VR in an artistic way is the continuation of second half of 20th century participatory art [Pop07]. With digital art, the viewer is invited to use his or her senses to interact or create with digital content, thus becoming an actor in the work of art that can be referred to as a "spectactor" [JRL13]. In performing arts using interactive devices, gestures are the center of the artwork, with a strong need for freedom of expression and technological support to evoke emotions through a dialectical experience.

The aesthetic experience of the captured gesture leads to states of presence and awareness allowing one to experience emotions and even to let go. In their research, Jego *et al.* [JM20] explain this possibility of letting go by a cohesion between inner resonance (the experience between a spectator and himself) and inter resonance (between a spectator and the artwork). We describe letting go in more detail in Sect. 2.3 In our work, we seek the emergence of a possible letting go through communication, curiosity and improvisation, as described by Jego *et al.*, but also through contemplation, wonder and introspection.

2.2. Collaborative digital Art

Collaborative digital Art in VR invites body to perform and communicate with other spectators in order to cocreate in a same virtual environment. This new type oh hybrid artistic artwork is defined by Joris Weijdom [Wei22] as a Performative Mixed Reality Experience (PMRE), i.e. “when the body purposefully becomes part of the aesthetic appreciation of the MR experience itself, including seeing other participants and the technology itself perform within the context of the artistic concept.”.

A collaborative artwork in VR is based on both individual and collective experience of immerged spectators. Thus, communication and collaboration are important stakes in a PMRE, each participant must become aware of its body, of its role, of its interactivity and other’s one. Ruddle’s research [RSJ02] present three levels of spectator’s co-action in a Collaborative Virtual Environment (CVE): (1) Actors can virtually see each other, (2) they individually manipulate a scene, (3) they manipulate together a same virtual object. In case of an artistic CVE, the third level is interesting because it allows to question roles asymmetry, synchronized co-creation, and communication between spectators and performers.

In a CVE, an important aspect that affects the quality of the collective experience and collaboration is the ability of participants to identify with their bodies or the bodies of others. Benford [BBF*95] describes embodiment as "the provision of appropriate body images to users in order to represent them to others and also to themselves". He identifies the body in VE as a source of continuous information of presence, location, identity, activity, availability, activity history, point of view, point of action, gesture, facial expression, and more.

According to Bevacqua et al. [BRSDL16], co-presence works in part with the embodiment of avatars, with a crucial role for the body in constructing meaning in our own world. We discover our environment through the result of our actions and perceptions, and we communicate through our gestures.

Many studies focus on the realistic or unrealistic appearance of an avatar in a CVE. For example, the research of Economou et al. [EDAG17] claims the importance of creating realistic avatars in a process of identification and awareness of our virtual body and that of others in a virtual world. On the other hand, Fraser et al. [FHBH04] assert the importance of creating an avatar focused on interactive capabilities rather than a realistic virtual humanoid whose real-time rendering problems could be a barrier to embodiment. With their research, they illustrate the possibility of collaborating with avatars composed of a simple frustum and arms. They also highlight the importance of field-of-view in communication and understanding of sensory capacities of an avatar [FBHH99]. Representing avatars’ eyes invites to make it clear that the immersed person can see me.

In a context dedicated to dance, Stergiou et al. [SERI19] study the performance of several spectators according to embodiment in semi-humanoid avatars (which partially represent a human body, or with non-realistic abilities). They show that variation in avatar appearance or abilities influences the style, expression, and quality of movement creativity.

It is important that each viewer can identify themselves and others in a virtual environment. Communication that enables co-creation depends on the ability to perceive our actions and those of others. Pauchet [PCL*07] determines the necessity of visual information and feedback to facilitate exchanges between actors and so collaboration. These feedbacks allow the spectators to understand their actions on the interactive objects, but also those of the others, thus allowing them to adapt their performance according to that of each participant.

Pinho et al. [PBF02] specify in their research the importance of freedom of action in a CVE. It is necessary that an immersed spectator can act in a natural way individually and cooperatively, having the possibility to switch from one to the other. We said earlier that PMRE is both individual and cooperative. It is through this personal experience that the spectator can develop his curiosity, his interpretation, until a possible state of "letting go" in a collaborative and creative act.

Therefore, the user’s avatar has a significant impact in the process of co-presence, co-perception and co-creation. Through its appearance, it facilitates the understanding of the possibilities of perception and interaction, it promotes communication between each immersed spectator, as well as freedom of action and thus a better individual and collaborative experience. These are important points of collaborative digital art because they allow a free creation through the body and movements, and thus a greater feeling of emotions.

2.3. Relaxation and letting go in VR

Virtual reality allows users to relax through the effect of contemplation of a pleasant environment, body engagement and immersion [RAB*21]. A natural environment would have significant effects on the emotions and perception of the user, thanks to a pleasant landscape [AMF*17]. Also, studies by [Mat13] show the importance of sound in the relaxation process in virtual reality, to help to immersion and contemplation. In a relaxing virtual environment,

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a user can therefore reduce his or her everyday stress through immersion and interactivity, even to the point of possibly letting go.

Letting go is a complex emotional state to analyze because it depends on each person. However, by this term, we describe a loss of self-control, of barriers and limits that we give ourselves. We also mention the state of mind of deep immersion in a virtual reality artwork, allowing an accentuation of the perceptions and thus of the emotions lived during the experience [FEM*08]. According to Jego, "through the experience of letting go, the body allows for a deeper integration with the sensory-motor system, the emotional state, and therefore with the environment around it" [JM20].

This is why it is interesting to evaluate the emotions felt by the spectators in the virtual experience, in order to try to understand if the relaxation can go to a state of letting go.

2.4. Emotion evaluation

According to [BL00], emotional evaluation depends on its three components:

1. The cognitive component. This part which corresponds to changes in mental state related to feelings and emotion, and refers to the evaluation that the subject makes of his own emotional state. It is evaluated through questionnaires such as the *Differential Emotion Scale (DES)* [Iza13], the *Self-Assessment Manikin scale (SAM* [BL94], or the *Brief Mood Introspection Scale (BMIS)* [Joh19].
2. The behavioral component. This part corresponds to facial, position, and movement cues. It can be evaluated by sensors, such as EMG and observations.
3. The physiological component. This part corresponds to changes in physiological changes such as heartbeat, blood flow, temperature,... The physiological-based evaluations of emotions use sensors such as the *electrodermal activity (EDA)* sensors that measures the changes in conductivity produced in the skin, *ECG* for heart rate monitoring, breathing rate monitoring, or *EEG* to capture brain activity.

The cognitive assessment of emotions is widely practiced in the psychological and medical fields. The behavioral approach to emotion assessment requires specific knowledge and training in order to decode facial or body expressions. Physiological sensors are widely used because they provide objective quantitative data, but at the cost of often invasive devices.

3. Motivation and contribution

We propose a collaborative virtual environment that immerses a user in an imaginary and dreamlike world inspired by romantic painting. We wish to offer to the spectators a moment of relaxation, well-being, even of letting go, through a shared experience of contemplation and co-creation of a landscape in which they find themselves, and where they are associated with a live artistic performance that accompanies and guides their discovery of this universe. An artwork is a global experience, so we chose to measure emotions on the whole artwork, rather than isolating each element like the music, the environment or the collaboration.

We think the cognitive approach of emotional evaluation is more suitable to the live artistic experience context proposed in our work. We chose to avoid sensor-based evaluation because they are invasive for the user experience and are likely to interfere with immersion and freedom of movement. We found several examples in the literature of the use of the BMIS for the evaluation of emotions in different artistic contexts, such as music [MM97], [Pha19], cinema [JJ19] or even the presence of art in hospital setting [HPFR15].

We therefore decided to use this emotion assessment tool in our context, although we did not find an equivalent use in virtual reality whose community uses mainly physiological sensors. In order to validate our research, we seek to evaluate the impact of the experience on the spectators, by focusing on their emotional state before and after the performance of the VR artwork as a whole.

The contribution of our work is at two levels, on the one hand the design and creation of the collaborative virtual artistic environment by an interdisciplinary team, and on the other hand a cognitive approach for the evaluation of the emotional impact of the artistic work on spectators.

4. Method

We now describe the method we followed to evaluate the impact of the "Creative Harmony" experience on its users. After a statement of our hypotheses, we first present the artistic design and the technical implementation of the "Creative Harmony" artwork. We then detail the experimental protocol set up for our evaluation as well as the results obtained.

4.1. Hypotheses

The first impact we want to evaluate is the change on the emotional state of the users, which we express through the hypothesis :
(H1): The "Creative Harmony" artistic experience have a positive impact on the mood of the participants, with an increase of positive mood indicators and a decrease of negative mood indicators.

In addition, we are interested in the co-creation experience felt by users, which we express through the hypothesis :
(H2): Users feel they are co-creating with other participants during the "Creative Harmony" experience.

Finally, we want to assess the feeling of letting go and relaxation experienced by users within the "Creative Harmony" artwork, which we express through the hypothesis :
(H3): Participants experienced letting-go and relaxation when immersed in "Creative Harmony".

4.2. Artwork design

The artwork offers to several spectators to be immersed in a same CVE, together with a performer, and to create and modulate a same generative landscape by captured movements and gestures. We distinguish two roles in the environment. A performer (role A) creates generative content by is movements, and spectators (role B) modulates this virtual content with gestures (Fig. 7).

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4.2.1. Artwork inspired by romantic painting

The aesthetic concept of Creative Harmony relies on the 19th century romantic philosophy inspiration. Our research is based on German romantic artists to raise live emotions to spectators, thanks to nature, void, nostalgia and large spaces representation. We want spectators to live as much collaboration feelings as contemplation. Thus, Creative Harmony's virtual environment is composed of a quite seabed for contemplative scenes and a dynamic auroral red sky for performer's interactive scene.

Sublime philosophy study and more precisely Edmond Burke's reflection [Rya01] permitted us to generate powerful landscapes in a digital painting technic, inviting contemplation and nostalgia. By including sublime figuration concepts, we modelized several islands and ruins representing our collective unconscious and personal universes of each artistic team member. We wanted to bring spectators to explore their personal space by discovering ours.

4.2.2. Avatars

An avatar is associated to the performer and spectators. Inspired by Fraser's research, we determined a semi-humanoid shape for interactive spectator embodiement. We wanted to develop an embodiement through nonrealistic forms, permitting performance to be fluid and non-ordinary for spectators. The avatar is composed of a moving particles cloud head, chest and hands. Two eyes on the head help to determine body sense, position and spectator field-of-view (Fig. 2). During a movement, particles move away from each other giving a fluid aspect to bodies. Hands particles lifetime is longer than others, creating an ephemeral trace in space, inviting spectator to move in the environment (Fig. 2). By creating tracings with their hands, spectators embody a performer and a painter role. Moreover, generated 3D drawings are expression and communication ways between each participant. Each one of them can create gestures series that are specifics to them, then imitate shapes of others permitting to create new personal expressions. Hands particles lifetime are longer in the time, proposing to spectators stronger explorations of space and communication.

4.2.3. Artwok structure

Creative Harmony is structured in three main phases, a first immersive and relaxing phase, a second interactive and co-creative phase, and a contemplation and communication third phase.

First phase : relaxation The first one is a phase of contemplation of an underwater landscape, in which animals, a whale, a turtle, and a sting ray in particles evolve. The spectators are alone and can hear a voice-over, associated to a calm music (Sect. 4.2.4) that invites them to relax and let themselves go in this universe (Fig. 1).

Second phase : interaction and co-creation The second phase is a co-creation phase between the performer and the participants. The performer is above the water and generates mountains with the movements of his arms (Fig. 2, bottom). At the same time, the spectators are underwater and are offered movements, which influence the mountains, either to make them grow or lower. The participants are visible to the performer through their avatars (Sect. 4.2.2). In the same way, they see themselves in the virtual world and see the performer in the center (Fig. 2, top).

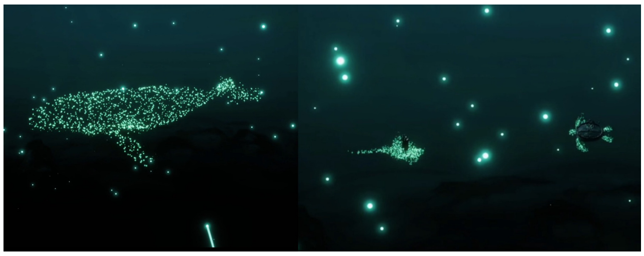

Figure 1: *Underwater relaxing environment in the first phase*

Figure 2: *The co-creation phase from underwater spectators point of view (top), and above water performer point of view (bottom)*

Third phase : contemplation and communication In the third phase, all the participants see themselves in the same environment, through their avatars. This one is constituted by the mountains generated previously, those having pushed up are on the ground while those having been descended by the participants are on top, like stalactites. In this scene, the particle trails left by the avatars' hands are extended to encourage the spectators' movements and also to give them a way to communicate with the other participants. The environment is enriched with a ballet of particle dancers pre-recorded from specific dance sessions with several professional dancers, organized during the creation phase of the project. Each movement of the dancers was captured by several body tracking sensors placed on dancers' body, who were performing on a VR Cave stage. Then, these recorded gestures where edited to create a virtual ballet that

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surrounds the avatars, helping spectators to bodily express themselves. These virtual dancers characters evolve in the time between humanoid form to abstract figures (Fig. 3).

Figure 3: *The last scene with spectators' and performer's avatars surrounded by the virtual ballet and the created landscape*

4.2.4. Soundspace

Associated to the VR design, an original music was created especially for Creative Harmony by a music composer. The all auditive artwork was created in a contrasted way, based on artist's emotions. Music power goes crescendo, with quiet moments for scene 1, rhythmic moments for scene 2 and shamanic ambient for third scene. The music brings to the audience as much depth of emotion as contemplation, inviting an eventual letting go.

4.3. Artwork technical implementation

The artwork was implemented using Unity 2018.4.1.f1 and a scenario engine #SEVEN (https://team.inria.fr/hybrid/xareus/) [CGBBA14]. The main technical components are the collaboration management and the procedural landscape generation presented below.

4.3.1. Network

Network implementation is based on the Unity API Mid level MLAPI. The network operates in a centralized manner: one Unity application serves as a server and all the clients, either Unity application for role A or Unity application for role B, connect to it (Fig. 4, left). The scene being presented, the generation of the mountains, the positions of the participants and animated elements in the scene are synchronized by a combination of different methods provided by MLAPI, Network objects, which are classic Unity objects instantiated on all clients, RPCs (Remote Procedure Call),synchronized variables, which propagates a modification of its value on one client to the other clients.

In addition, we integrated another synchronization tool in order to deploy or application on a cluster of PCs for a four-sides Immersive Physical Environment (IPE) facility. This second synchronization is based on MiddleVR (https://www.middlevr.com/), using a master/slaves model. In this case, only one Unity instance, the master, communicates with the server, and the slaves are synchonized with the master through MiddleVR (Fig. 4, right).

There is no theoretical limit to the number of connections. A technical test was performed with one server instance, 14 Role A instances on the IPE facility, 5 Role B instances on HMDs, and one additional instance to generate general point of view of the scenes with no incidence on the performance of the application.

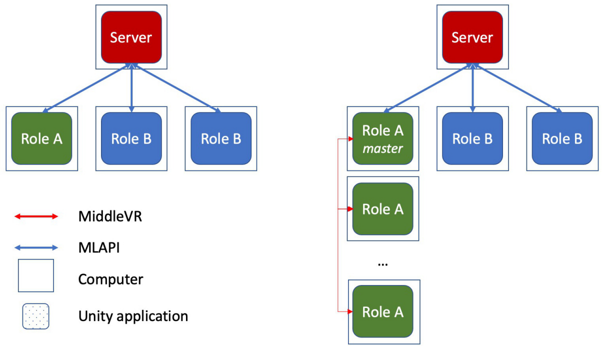

Figure 4: *General network architecture of the application (left), and extension for cluster integration (right) .*

4.3.2. Mountains generation

Central element of the landscape, the mountains are procedurally generated from the performer movements, through the deformation of a mesh based on a horizontal disc pierced in the center that surrounds the center of the scene where users are positioned. The mountains are generated through the modification of the vertical coordinate of the points of the mesh that are impacted by the movements of the performer. The impacted point are determined by the variation of the hands' positions with respect to an invisible smaller disk centered on the head. Only the ascendant motions of the hands are recorded, and mountains will then grow at the location P' corresponding the point P which is the projection of the hand position on the small disk to the mountains disk (Fig. 5).

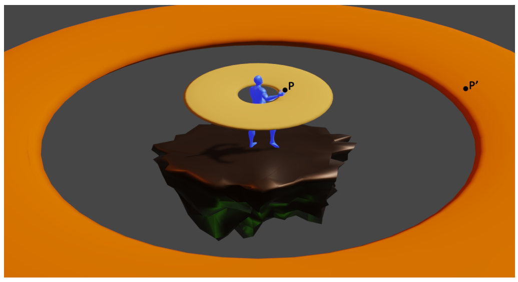

Figure 5: *Mountain generation from the performer motion.*

The generated mountains can be modified by spectators thanks to a repeated gestures system. During the artwork conception, we recorded series of less or more complex gestures in a virtual space. These recorded gestures appear as colored particles oriented trails around spectators during all the second scene (Fig. 6). Spectator must imitate by passing his hand through all the colored trail, triggering several feedbacks. Colored trail becomes green, controllers vibrate, particles appear on affected mountain and sounds can be

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heard. Proposed gesture complexity evolves with experience time, inviting spectator to explore as much as he can the virtual area.

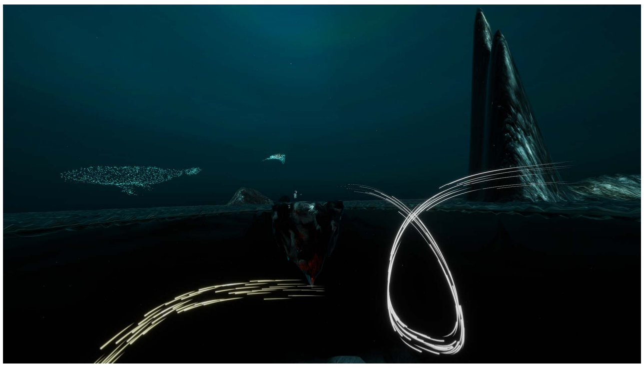

Figure 6: *Example of recorded gesture appearing around spectators with two particles trails to be followed by the spectator's hand. Disc in background is the area where generated mountains appear.*

4.4. Experiment protocol

The experiment was scheduled on 2 days, with slots of 40 minutes. The participants were convened in pairs to enable collaboration. The experiment was organized in 5 phases, (i) consent form with written presentation of the experiment goals, (ii) self-assessment of the mood state, (iii), presentation by the artist-performer of the equipment, the context of the artwork, and the interactions, (iv) collaborative artistic experience during 17 minutes, (v) self-assessment of the mood state and subjective questionnaire.

4.5. Apparatus

For the experimentation, the performer was dancing in in a 9.6m×3m×3.1m (width, depth, and height) 4-sided IPE (Fig. 8) equipped with 14 WQXGA projectors. Performer's head and hands were tracked with 6 degrees of freedom passive markers using an Optitrack optical tracking system with 16 cameras at an update rate of 120Hz. The two participants were wearing HTC Vive Pro HMDs with one controler in each hand, and were located in two different physical spaces, one in the same room than the performer, the other one in an adjacent closed room. Both participants evolved in a 2*m* x 2.5*m* area. The organization of the installation is presented in Fig. 7, photographic views of the three spaces are presented in Fig. 8

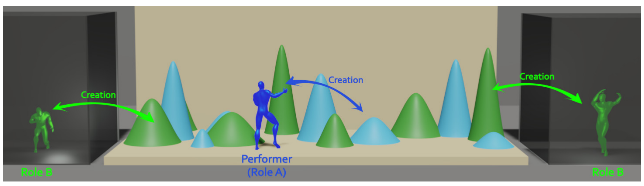

Figure 7: *Principle of the installation for the experiment.*

Figure 8: *Pictures of the three spaces, the performer (center) and the 2 participants (left and right).*

Brief Mood Introspection Scale (BMIS)

INSTRUCTIONS: Circle the response on the scale below that indicates how well each adjective describes your present mood.

definitely do not feel	do not feel	slightly feel	definitely feel
XX	X	V	VV

Lively	XX X V VV	Drowsy	XX X V VV
Happy	XX X V VV	Grouchy	XX X V VV
Sad	XX X V VV	Peppy	XX X V VV
Tired	XX X V VV	Nervous	XX X V VV
Caring	XX X V VV	Calm	XX X V VV
Content	XX X V VV	Loving	XX X V VV
Gloomy	XX X V VV	Fed up	XX X V VV
Jittery	XX X V VV	Active	XX X V VV

Table 1: *BMIS questionnaire*

4.6. Recorded data

As the experiment focuses on the impact of the artistic experience on the user, we asked the participants to perform a self-assessment of their emotional state with the BMIS tool just before and after the experience. The BMIS scale is an open-source mood scale [MG88] consisting of 16 mood-adjectives presented in Tab. 1, eight positive (*Active, Calm, Caring, Content, Happy, Lively, Loving, and Peppy*), and eight negative (*Drowsy, Fed up, Gloomy, Grouchy, Jittery, Nervous, Sad, and Tired*), associated with a scale of four values, XX, X, V, and VV corresponding to a range of appreciation from *definitely do not feel* to *definitely feel*. Four indicators can be computed from the BMIS: Pleasant-Unpleasant, Arousal-Calm, Positive-Tired and Negative-Relaxed Mood. Pleasant-Unpleasant and Positive-Tired are considered as positive mood indicators while Arousal-Calm and Negative-Relaxed are considered as negative mood indicators. Each score is computed from a different scale (set of items) containing a different number of items. Depending of the indicator, some mood adjectives are valued from 1 to 4, ranging from XX to VV, and some other mood adjectives are reversely valued from 4 to 1 ranging from XX to VV. Pleasant-Unpleasant uses all 16 items, with a reversal of all the negative adjectives, Arousal-Calm, 12 items (*Active, Caring, Fed up, Gloomy, Jittery, Lively, Loving, Nervous, Peppy, Sad, rev(Calm), and rev(Tired)*), Positive-Tired, 7-items (*Active, Caring, Lively, Loving, Peppy, rev(Drowsy), and rev(Tired)*), and Negative-Relaxed, 6 items (*Fed up, Gloomy, Jittery, Nervous, Sad, and rev(Calm)*), where *rev(m)* indicates that the adjective must be reversed in the computation. The validation of the hypothesis (H1) will be based on the observed variation on these four indicators.

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Id	Question
GEN1	How comfortable did you feel with the experience?
GEN2	To what extent did you feel "really there" in the virtual experience?
GEN3	To what extent have you forgotten the real space?
GEN4	How has the music impacted your experience of the work?
BOD1	To what extent did you feel that you were physically present in the VE
BOD2	To what extent have you forgotten your real body in favor of your virtual body
BOD3	To what extent did you feel the need to physically explore the virtual space through your real body?
BOD4	Did you feel a change in your breathing or body attitude during your experience?
BOD5	How much shortness of breath or muscle fatigue did you feel during the experiment?
INT1	To what extent did you feel like a creator of the virtual landscape?
INT2	To what extent have the particles in your hands helped you to move and create?
COL1	To what extent did you feel your partner's presence through their virtual body?
COL2	To what extent were you able to exchange gestures with your experience partner?
COL3	How much did you feel the collaboration with your partner on the virtual landscape?
LET1	Did you feel relaxed in the scene?
LET2	To what extent did you feel the sensation of letting go (feeling of well-being, letting go, relaxation of muscles, desire to dance, ...)
LET3	How much did you enjoy contemplating?
LET4	How much fun did you have interacting with the environment?
LET5	To what extent have you felt the urge to explore gestures that you are not used to do?

Table 2: *Questionnaire content*

Indicator	Mean	*SD*	*p-val*
PU	3.8	3.1	0.5
AC	-0.5	3.8	0.8
PT	1.5	2.9	0.7
NR	-1.6	1.9	0.5

Table 3: *Shapiro-Wilk test for the difference of indicators before and after the experience*

Pleasant-Unpleasant				Arousal-Calm			
$\|t\|$	**df**	$p-val$		$\|t\|$	**df**	$p-val$	
6.62	27	<0.01		0.64	27	0.5	
Measure	**Size**	**Mean**	*SD*	**Measure**	**Size**	**Mean**	*SD*
Before	28	48.93	4.06	Before	28	28.29	3.58
After	28	52.75	4.07	After	28	27.82	4.39
Positive-Tired				Negative-Relaxed			
$\|t\|$	**df**	$p-val$		$\|t\|$	**df**	$p-val$	
2.75	27	0.01		4.70	27	<0.01	
Measure	**Size**	**Mean**	*SD*	**Measure**	**Size**	**Mean**	*SD*
Before	28	20.11	2.27	Before	28	11.39	2.50
After	28	21.61	3.30	After	28	9.75	2.32

Table 4: *Bilateral paired Student test for the BMIS indicators*

At the end of the experiment, in addition to the post-experience BMIS scale, participants had to fill a questionnaire of 19 questions presented in Tab. 2 in order to gather subjective information about the overall experience (GEN1 to GEN4), the body feeling (BOD1 to BOD5), interaction (INT1 and INT2), collaboration (COL1 to COL3), and letting go (LET1 to LET5). The answers to the questions was based on a 7-likert scale with 1 being very little and 7 being a lot.

The validation of the hypothesis (H2) on co-creation will be based on the mean score of INT1, COL1, COL2 and COL3, which we expect to be greater than 5. The validation of (H3) on letting-go and relaxation will be based on the mean score of BOD3, BOD4, and LET1 to LET5, which we expect to be greater than 5.

4.7. Participants

28 people participated in the experiment, aged between 20 and 43 ($\bar{x} = 25.9, SD = 5.6$). All participants were informed about the procedure and gave their informed consent without retribution.

5. Results

5.1. Mood impact analysis

In order to evaluate the impact of the experience we calculated the four standard indicators Pleasant-Unpleasant (PU), Arousal-Calm (AC), Positive-Tired (PT) and Negative-Relaxed (NR) before and after from the BMIS scale, using reverse scoring method [Joh19]. We performed a bilateral paired Student test on these four indicators after that a Shapiro-Wilk test confirmed the differences between before and after the experience, followed a normal law as presented in Tab. 3. The results of the Student test are presented in Tab. 4. The bilateral paired Student test indicates a significant difference for PU, PT and NR indicators (Student absolute value t greater than the reference critical value for an alpha risk of 5% and a degree of freedom of 27 whose value is 1.703). The PU indicator significantly increased by 3.82. The PT indicator increased by 1.5 and NR decreased by 1.6, validating (H1) of the experiment.

Tab. 5 displays the average variation for each mood adjective. It is noticeable that the *Calm* mood adjective significantly increased while *Tired* and *Nervous* significantly decreased.

5.2. Questionnaires

Tab. 6 displays the mean, the standard deviation and the *pvalue* obtained from a Shapiro-Wilk test.

Highest significant scores (>6) are associated to GEN4 (Music), BOD3 and INT2 (Body motion), and LET3 (Enjoy). Lowest score (<2) is associated to BOD5 (Fatigue). Questions related to presence

Mood	Mean	SD	Mood	Mean	SD
Lively	-0.11	0.83	Drowsy	-0.32	0.61
Happy	0.21	0.57	Grouchy	-0.14	0.45
Sad	0.07	0.60	Peppy	0.29	0.81
Tired	-0.57	0.92	Nervous	-0.75	0.65
Caring	0	0.72	Calm	0.5	0.69
Content	0.32	0.67	Loving	0.25	0.75
Gloomy	0.18	0.82	Fed up	-0.29	0.60
Jittery	-0.36	1.13	Active	0.18	0.98

Table 5: *Mood adjectives average evolution between before and after the experience*

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Id	Mean	SD	*p-val*	Id	Mean	SD	*p-val*
GEN1	5.68	1.06	0.006	INT2	6.07	1.02	<0.001
GEN2	5.46	1.20	0.01	COL1	5	1.28	0.007
GEN3	5.64	1.13	0.007	COL2	3.54	1.60	0.02
GEN4	6.21	1.26	<0.001	COL3	2.39	1.31	<0.001
BOD1	5.46	0.96	0.005	LET1	5.64	1.13	0.006
BOD2	4.68	1.48	0.01	LET2	5.29	1.49	0.007
BOD3	6.03	1.07	<0.001	LET3	6.54	0.84	<0.001
BOD4	4.57	1.60	0.008	LET4	5.68	1.36	<0.001
BOD5	1.57	1.03	<0.001	LET5	5.89	1.13	<0.001
INT1	3.43	1.43	0.01				

Table 6: *Questionnaire results*

(GEN2, GEN3, BOD1 and BOD2) are all above 4.5, indicating a good feeling of presence.

The co-creation indicator obtains a score of ($\bar{x} = 3.59, SD = 0.94$, *p-value*=0.02), invalidating (H2). The letting-go indicator obtains a score of ($\bar{x} = 5.66, SD = 0.81$, *p-value*=0.26). The *p-value* indicates a non-significant result for this indicator, which prevents us from concluding to the validity of the hypothesis. However, we can notice that participants expressed a high level of letting go feeling with significant scores of LET1, LET2 and LET5 above 5. The feeling of joy and fun expressed in LET3 and LET4 received also significant high scores.

6. Discussion

The main indicator of the BMIS, Pleasant-Unpleasant, shows a significant positive impact on the emotional state of the users. This finding is reinforced by the significant positive evolution of the Positive-Tired indicator and the negative evolution of the Negative-Relaxed indicator. We can therefore conclude that the Creative Harmony experiment has allowed to modify the emotional state of the users, in particular towards a relaxed state (Negative-Relaxed indicator). By studying more precisely the evolutions of the mood adjectives, we notice that the biggest decreases of emotions are fatigue and nervousness (negative emotions) and on the contrary, the biggest increases are calmness, being happy and content. The two biggest changes being nervousness and calmness, which suggests that a relaxing effect was indeed observed following the Creative Harmony experiment, despite the fact that the indicator we chose to use was not conclusive.

The effects observed on the emotional state of the users are linked to the cognitive component, which is the component that seemed to us the most adapted to the artistic context of the experiment. However, it would be interesting to investigate the impact on the other components of the emotion, especially physiological, by integrating light sensors of the EDA type which could improve measuring the level of relaxation. The behavioral component seems more complicated to evaluate in our context, but could be based for example on a measurement of the evolution of the amplitude of the movements of the users during the experience.

It should be pointed out that relaxation, personal well-being and letting go are complicated concepts to study objectively, as they depend on the experiences and limits of each individual. Despite the plurality of emotional evaluation tests, we cannot have a uniform result for all spectators. We found a general and significant movement of emotions. But we cannot say that each individual reached a state of great relaxation or even of letting go as we define it. In the same way, the lived experience evolves between each spectator. Some may be very contemplative, others very active, while having similar emotional results.

The questionnaires and users feedback showed that the collaboration in the process of creating the landscape was not sufficiently noticeable. The spectators with role B understood that their movements caused changes, they could see themselves with the performer, but they did not have the feeling to control the evolution of the landscape. There is indeed co-creation in that each spectator's movements impact the generative landscape, but there is no co-manipulation because spectator B cannot control exactly what generation he or she causes. This last point could be reflected upon and developed in future work, in order to evaluate the performance of a spectator immersed in a co-manipulative collaboration in virtual reality artwork.

The Creative Harmony experience has already been exhibited in several art festivals with positive feedback from the audience. We also extended the scenography to add a set of passive spectators who attended the performance in the IPE, with a stereoscopic view of the stage projected on the screens. It would also be interesting to analyze the impact of the experience on these passive spectators and compare it with that observed on active spectators with HMDs.

7. CONCLUSIONS

We presented the creation, design and implementation of the artistic co-creative VR environment Creative Harmony. The resulting artwork is based on a CVE whose aesthetic is inspired from 19th century German Romantic painting. An original musical creation associated to a live dance performance support the contemplation and exploration ot the dreamlike universe.

We evaluated the impact of the artistic virtual experience on users' emotional state before and after their performance in VR. We proposed a method based on a cognitive approach to evaluate this impact, with a standard tool widely used in psychological studies, the BMIS scale. The study of these results highlighted a significant impact on the emotional state of the participants with increase of positive mood indicators and decrease of negative ones, with the highest evolution for tiredness, nervousness, calmness and happiness.

Future works will intend to explore other emotional components in order to refine and extend our current results. An improvement of the co-creation model is also under investigation, in order to enable a better control and collaboration feeling by the users.

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