Evaluation of the Relationship Between Virtual Environments and Emotions

Tiago Oliveira[1(✉)], Paulo Noriega[1,2], Francisco Rebelo[1,2], and Regina Heidrich[3]

[1] Ergonomics Laboratory, Faculdade de Motricidade Humana, Universidade de Lisboa, Estrada da Costa, 1499-002 Cruz Quebrada, Portugal
t.oliveira2010@gmail.com

[2] CIAUD, Faculdade de Arquitetura, Universidade de Lisboa, Rua Sá Nogueira, Pólo Universitário, Alto da Ajuda, 1349-063 Lisbon, Portugal

[3] Pró-reitoria de Pesquisa e Inovação, Universidade Feevale, Rodovia RS-239, 2755, Novo Hamburgo, RS 93352-000, Brazil

Abstract. This study describes the emotional responses to the use of virtual reality (VR) environments. Namely the relation between different environments and axial emotional dimensions: valence, arousal and dominance. To better understand this relation, were also evaluated presence, concentration, relaxation. We evaluated the experience of 146 participants in three virtual environments: Helix® (a roller coaster experience); Yana® (a beach sunset/sunrise experience); Surge® (an abstract environment transformation experience). Helix® proved to be a facilitator of presence and arousal. Surge® results are like the Helix® except that levels of relaxation are lower. Yana® is a facilitator of dominance but levels of arousal and presence was the lowest of the three. The presence was positively related with arousal. Relaxation had a negative relation with arousal and presence. The emotional appraisals were different for each environment. These results are useful in developing virtual environments to model emotional experience.

Keywords: UX · Emotion · Virtual environments · Presence · Valence · Arousal · Dominance · Concentration · Relaxation

1 Introduction

Presently, every day new VR contents appear on VR market. The VR market grows exponentially according to Digi-Capital's market projections [1], VR combined profits with augmented reality profits will reach $ 150 billion by 2020 [1].

The growing of internet speed and bandwidth, even for mobile smartphones, provide an excellent opportunity for development of augmented reality and virtual reality applications. Take the example of the Nintendo successful augmented reality game Pokémon go, or the VR cardboard that allow with a smartphone and a small investment, the users enjoy a VR experience.

The massification of VR demands UX evaluation of the contents, namely the evaluation of emotions elicited by VR experience. Do different experiences in virtual reality also trigger differentiated emotions as in a real situation? For example, will the arousal

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caused by traveling on a VR roller coaster far outweigh an arousal of watching a sunset on a beach? How to measure the emotional response resulting from the VR content?

Several definitions of emotion are presented in the literature by those who are interested in this topic. According to Kleinginna and Kleinginna [2], the main problem in the field of emotions is the variety of proposed definitions. Different fields of study such as psychology, neuroscience, or design enrich the knowledge we have about emotions. However, consensus is difficult to find because different domains tend to focus on different phenomena of emotion [3].

In a consensus attempt between 92 definitions and 9 skeptical statements [2] the perspective that the emotion would be: "A complex set of interactions between subjective and objective factors, mediated by the neurological/hormonal systems, which can (a) originate affective experiences such as arousal, pleasure/displeasure; (b) generate cognitive processes, such as relevant perceptual effects, evaluations, process designations; (c) activating vast physiological adaptations to excitation conditions; And, (d) conduct behavior, which is usually, although not always, expressive, directed to a focus, and adaptive". This definition reveals, from the outset, duality of emotion components, composed of an internal, subjective component, and the peripheral component, the expressive part of emotion as a repercussion phenomenon in the different response systems that may be reflected in changes in physiological, neurological or Behavioral, and everything is mediated by the neurological/hormonal system.

Emotion research in UX, should be appropriate to the nature of the emotion, the type of product being analyzed, the characteristics of the sample, and the time we have available to obtain and treat the results. Behavioral measures (changes in tone of voice, facial expressions), physiological (body temperature, heart rate, respiration, blood pressure, electrodermal changes, muscular tension) and neurological (evoked potentials) are sensitive to emotions. However, it is more common to evaluate emotions with the application of questionnaires, free descriptions, response scales or lists of adjectives.

Emotions have been represented in specific categories or in continuous dimensions or factors, depending in a use of a categorical perspective or a dimensional approach. Thus, the emphasis can be placed on the characterization of the different categories of specific emotions (categorical perspective) or the identification of the structure of the emotions (dimensional perspective) [4].

The dimensional model proposed by Wundt [5] structures the emotions by their position in n-dimensional space. There are some fundamental dimensions for organizing an emotional response by the dimensional model [6] for example, emotions can vary in their position in three dimensions: pleasure-displeasure, calm-aroused/excited, inattentive-attentive [5]. In some studies, the most common dimensions are: valence, arousal and approach (avoidance) [7, 8]. The dimensions' valence, arousal is a continuous variable in the states of unpleasure - pleasure, and the arousal goes from calm to excited.

According to Warriner et al. [9], in a three-dimensional perspective, three dimensions are commonly used: valence of the stimulus; arousal or excitement provoked by the stimulus; and the dominance, or degree of dominance of the control exercised by the stimulus. This three-dimensional approach is the one that will be used in this study.

Affective valence is pointed out as the main measure, it reveals the emotional nature of the stimulus, and is positively related to the mobilization of cognitive resources such

as concentration [8, 10, 11], identify the level of arousal as the second most important dimension of emotion representation [12], and increase the evidence of its importance.

In some studies, [11, 13, 14] the dominance is not used, choosing only valence and arousal, thus structuring the approach to emotion in a two-dimensional perspective [15]. In this study a three-dimensional approach will be used, where it will be executed through the Self Assessment Manikin (SAM) instrument. SAM is a pictorial technique and was originally implemented in an interactive computer program, only later appears the paper version [16]. The dimensions evaluated by the SAM are respectively: valence, arousal and dominance with the respective semantic differential scales (unpleasure-pleasure; calm-excited; dominated-dominant). In valence, the SAM pictograms range from a figure with a ripped smile, to a figure with an unhappy expression. On arousal, the pictograms range from a restless and excited figure to a figure who seems to be sleeping. In the dominance dimension the pictograms go from a figure that occupies the whole space, dominating completely, until a small figure inserted in the space, dominated by the event. It also presents the advantages of being able to reduce the biases associated with verbal measures and is quick and easy to administer [16].

The UX aspects of technology should also be evaluated. What is the role of immersion? In virtual environments, immersion is something objective and entirely dependent on technology. The virtual presence is the subjective state of consciousness that allows the user of a virtual system to feel that it is in this environment, even knowing that it is physically in another place [17, 18] and in the literature several studies have shown that the more immersive a technology is the greater the user's presence in the environment [19–21]. The presence is thus a dimensional construct that is described by the extension of emotional responses to a virtual environment [19, 22, 23].

Undoubtedly the feeling of presence does not depend only on immersion, it also depends on the interaction and perceptual realism of the virtual system [24]. However, it is also unanimous to affirm that the sense of presence varies per the nature of the content experienced [19, 22, 23, 25].

Thus, the presence in this study will be measured to better know the relationship that is established between the dimensions (valence, arousal, dominance) as a function of the content experienced (VR environment). In this perspective, will also measure concentration and relaxation. In this way, it is intended to know the emotional responses generated by VR environments, identifying the relationships that are established between different environments and their respective emotional dimensions: valence, arousal and dominance. It is expected to find significant differences between the three VR environments.

The Yana environment is per the authors a VR relaxation program, in this way it is expected that this environment would be perceived as an inducer of relaxation. Roller coaster riding is quite adrenergic activity; in this way, it is expected to be perceived as an inducer of arousal and Presence. It is also intended to test the possibility of gender moderation in the manifestation of responses, since the literature in other contexts refers to differences in the way emotions are felt and expressed. Women, when compared with men, tend to be more expressive [26] and to report negative emotions (fear, sadness, guilt and shame) more frequently, intensely, and triggered [27], while men tend to report

more often and more intensely negative emotions such as anger and contempt [28], and to show greater arousal before Certain types of positive (e.g., sexual) stimuli [29].

The results obtained could help to understand the emotional relation that non-users and users have with VR, and the subjective perceptions that emerge from the use of VR content. In this perspective, this study is not only interested in the development of content from the emotional point of view, more efficient, effective and with greater satisfaction for the user, but also serves as a prelude to future studies.

2 Methodology

2.1 Stimuli

Three different VR environments were chosen. The 3 environments are animated to 360°, and do not require actions on the part of the user that alter the natural evolution of the events. The contents were chosen because they are user-specific, categorically different and short-lived (less than 9 min). The involvement does not concern virtual involvement, but rather a psychological state necessary to create presence because depends to the individual degree of significance attached to the stimulus, activity or event [30]. So, we think that the activities suggested by the chosen environments (e.g. watching a sunset, or riding a roller coaster) are felt as distinct envelopes. In this way, it is expected that the user experience resulting from the visualization of distinct VR environments will trigger different emotional responses. On the other hand, we were interested in the fact that the chosen environments do not require user actions to unfold events, since the literature indicates that in addition to the immersion and the perceptual realism, the interaction when well designed, acts as a facilitator for the sensation [31]. In this paper, we present the results of the present study [24, 32, 33]. Thus, we isolate the possible interference of the interaction variable of our study, to better understand the relationship between the environments, and the users' emotional experience.

The first environment Helix® is a roller coaster experience:

Helix® Roller Coaster VR, was developed by Archivision® and is a virtual roller coaster.

Description:

At first he stands and notices that he is sitting on a roller coaster chair, however he is not alone he has an avatar sitting next to him (Fig. 1a). When you look back you notice that all the chairs are occupied.

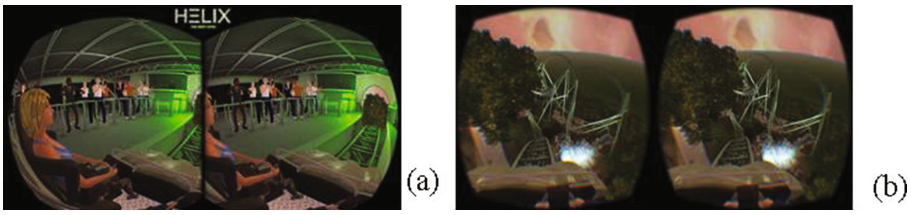

Fig. 1. .

Ride starts, during the departure there are flat routes, medium and high slope elevation, loopings, lateral rotations and steep descents (Fig. 1b).

During the ride the sound environment is composed of electronic music and the enthusiastic cries of avatars.

This environment was chosen because we thought it be the most adrenergic of the 3 environments.

The second Yana® Virtual Relaxation environment is a paradisiac beach:

Developed by The Campfire Union Inc.

Description:

It is a relaxing experience where the user is on a beach with palm trees and white sand. In the middle of the water a rocky formation imposes itself, its image is reflected in the calm waters (Fig. 2a). The sun goes down giving way to the night (Fig. 2b). During the night time the user observes a sky full of constellations and falling stars, on the horizon a sailboat appears from right to left. The night finally ends with a new sunrise. In the sound environment, you can hear seagulls and other birds, accompanied by the sound of Tibetan bowls, bells, and the sound of the waves of the sea.

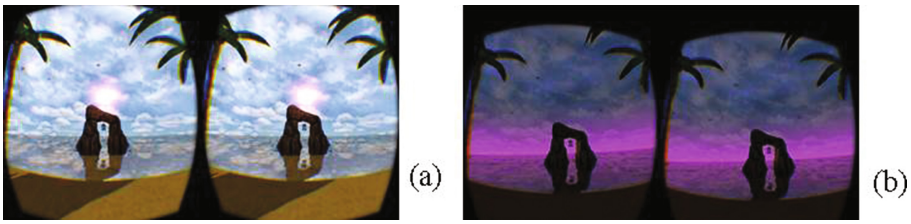

Fig. 2. .

This environment was chosen because we thought it to be the least adrenergic of the 3.

The third environment is the Surge®:

A third environment, Surge®, was created by 3D artist and musician Arjan Van Meerten. This environment is considered one of the first real-time VR music videos - “first real time VR music video”. This VR experience is more abstract. The user witnesses a transformation of the environment, in which the floor becomes cubes (Fig. 3a) that oscillate in coordination with the music. The cubes on the floor rise and glimpses giant humanoid silhouettes (Fig. 3b) that move to the rhythm of an electronic ambient sound. This environment was chosen because we thought it should induce a high arousal state due to its unpredictable and abstract nature.

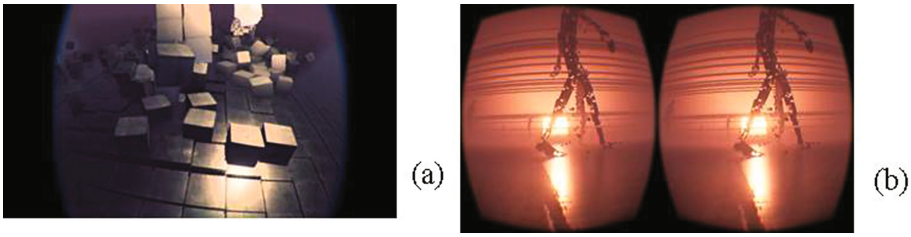

Fig. 3. .

2.2 Participants

Participants (n = 146, 103 males and 43 females) with a mean age of 30.65 years, and standard deviation 14 (min = 18 years, Max = 71 years) are a convenience sample recruited for the study in three Public events held in Portugal (GreenFest 2015, n = 40; Futuralia 2015, n = 63; Portuguese Navy Day 2015, n = 43).

Participants were randomly divided into 3 groups:

- n1 = 40 participants experienced Yana® (70% male 30% female), mean age 24.18 and standard deviation 9,969;
- n2 = 63 experienced Surge® (77% male, 33% female), mean age 28.75 and standard deviation = 13,421;
- n3 = 43 Helix® - Virtual Roller Coaster (75% male, 25% female), with mean age 39.47 and standard deviation = 13,866.

All the participants affirmed never had cardiac pathologies, nor manifestations of epilepsy. All female participants also stated that they were not in gestation.

2.3 Evaluation Questionnaire

The focus of our study is the analysis of the relationship of the virtual environment with the conscious emotional experience, thus, as a measurement instrument, a questionnaire was used.

Literature in other contexts criticizes questionnaire exclusive use [34] because non-conscious emotions, in which physiological reactivity tends to become evident, can be independent of a concomitant subjective perception of emotional response [35]. However, due to practical constrains, there was an impossibility of applying psycho-physiological methods. Data collection was done in public events (fairs), so the time available for evaluation for each participant was short, so it was impossible to use a psychophysiological method whose preparation is more time consuming.

In order to make an evaluation compatible with the objectives of the study and the temporal constraints of this type of events, a questionnaire with two parts was constructed, one applied before the experience of the VR and another after. In the questionnaire applied before the VR experience: some sociodemographic questions were asked (age, gender, level of education, nationality); two questions regarding prior knowledge and use of VR; two issues concerning the habit of playing FPS (first player

shooter). As control measure, participants was asked about their expectations of the experience they were about to have regarding the same variables evaluated after the experience. Thus, valence, arousal, and dominance were measured using the SAM (self-assessment-manikin); Presence was measured with semantic anchors with 9 degrees of freedom.

In the questionnaire applied after the experience in VR the same previous measures was obtained.

2.4 Experimental Design

In the study, independent samples were used and participants experience in three virtual environments was evaluated. The independent variable is the environment (Helix® - RollerCoaster, Yana®VirtualRelaxation, Surge®), and the emotional dimensions: valence; arousal; Dominance, the dependent variables. For greater experimental control were also measured the presence, concentration and relaxation variables.

Participants answered a questionnaire before experiencing the virtual environment, and answered the second part of the questionnaire after exposure to the virtual environment.

2.5 General Objective

– Know the emotional appraisals generated by virtual reality environments.

2.6 Specific Objective

– Identify relationships between different virtual environments and emotional dimensions: valence, arousal, dominance.

2.7 Experimental Protocol

During all the experimental periods, we counted with help of volunteers of the degree in Ergonomics of the Faculty of Human Kinetic who duly conscientized and informed about the intent of our study registered the values and organized the participants. All participants in the study had access to informed consent and in a free and uncommitted manner, they agreed to participate in the study in exchange for experiencing an VR environment.

The content of the VR experience was unknown to the participants; they just knew it was an VR environment. Thus, we can assume that participants participated in the study for the sake of curiosity in experimenting VR. Each participant only experienced an environment. Being the choice of the random environment without prior knowledge of the participant.

Before entering the questionnaire, the researcher alerts the participant that there are no right or wrong answers. The answers to the questionnaire should be the participant's

perceptions regarding what is questioned. It is also pointed out that the participant can leave the experience at any time for any reason that the participant finds imperative.

The participant then responds to some sociodemographic questions, and to a subjective questionnaire about how he expects to feel with VR experience. After the response, the participant places the Head-Mounted-Display (HMD), which with the help of the researcher is adjusted to the head, until the participant says that he is comfortable. The researcher then supplies headphones, and informs that the participant must adjust the sound to a sound intensity that is comfortable. After all, properly adjusted, the participant tells when to start the VR experience.

At the end of the experiment, the researcher helps to remove the headphones to the participant. The participant withdraws the HMD. The researcher asks the participant if he/she is willing. With the positive response, the researcher immediately manages the second moment of measurement at this point, the participant responds according to what he experienced with experience that he had in VR. The emotional responses generated by virtual reality environments.

3 Results

As described in the experimental design we used an independent sample with a total n = 146 distributed respectively by: n1 = 40 Yana® + n2 = 63 Surge®, n3 = 43 Helix® - RollerCoasterVR). Using the SPSS software, all statistical tests were performed.

As a control measure the participants' expectations of VR were evaluated and that there were no differences between these expectations.

To verify if there was significant differences between the emotional responses generated by the three VR environments, since the samples are independent and cannot be assumed normal in the distributions, a non-parametric Kruskal-Wallis 1-Way ANOVA (k samples), with multiple comparisons between all pairs to compare the distribution among the k environments, where k (1, 2, 3), respectively (Yana®, Surge®, Helix®), with the hypotheses:

H0 = The distributions of the measurements are identical in the k * environments
VS
H1 = The distributions of the measurements are different in the k * environments, with i = 1, 2, 3, (being "k" the environment), Yana®, Surge® and Helix®, respectively.

We verified that there were no significant differences in the variables:

- Valence (displeasure/pleasure), $p > 0.05$;
- Dominance (dominated/domain), $p > 0.05$.

Significant differences between the 3 environments were observed in the variables:

- Arousal (calm/excited), for a test statistic value 52,118 corresponds to a $p < 0.001$.
- Presence, for a test statistic value of 18.512 corresponds to a $p < 0.001$.
- Concentration during RV (nothing concentrated/very Concentrated), for a test statistic value of 8.009 corresponds to a p-value of $p < 0.05$.

- Relaxation during RV (nothing relaxed/very relaxed), for a test statistic value 41.423 corresponds to $p < 0.001$.
- Relaxation at the end RV (nothing relaxed/very relaxed), for a test statistic value 31.010 corresponds to $p < 0.001$.

To verify if there was significant differences induced by gender in the emotional states resulting from the experiment, a Mann-Whitney U test was performed for each environment. No significant differences were found in the Yana® and Helix® environments (Tables 1 and 2).

Table 1. Summary of results (mean, standard deviation) obtained in the studied environments

Variables	Statistics	Yana®	Surge®	Helix®
Arousal	Mean	3.15	5.78	7.40
	Std. deviation	1.49	2.74	1.42
Valence	Mean	7.93	7.71	8.21
	Std. deviation	1.07	1.68	0.99
Dominance	Mean	6.38	5.19	5.60
	Std. deviation	2.35	2.65	2.71
Presence	Mean	6.88	7.79	8.30
	Std. deviation	1.94	1.78	1.34
Concentration (during)	Mean	7.43	7.43	8.05
	Std. deviation	1.36	1.29	0.87
Relaxation (during)	Mean	7.45	4.43	5.88
	Std. deviation	1.22	2.17	2.11
Relaxation (after)	Mean	7.40	5.03	6.42
	Std. deviation	1.34	2.13	1.96

Table 2. Environment as facilitator of variables: arousal; presence; concentration; relaxation

	Arousal	Presence	Concentration	Relaxation
More facilitator	Helix®	Helix®	Helix®	Yana®
Less facilitator	Yana®	Yana®	Yana®/Surge®	Surge®

The results obtained in the Helix® environment confirm our hypothesis as the most exciting and provocative of the greater sense of presence in the 3 environments studied. On the opposite side as expected, the Yana® confirms our initial hypothesis. The Surge environment proves to be a more exciting stimulus in the arousal variable than the Yana®, however, and as expected, less than the Helix® environment.

4 Discussion and Conclusion

The results obtained clearly show that different environments elicited different emotions. For instance, participants' arousal was as expected. Roller coaster provoked the highest

arousal and the sunset beach of Yana the lowest arousal. Yana provoked the highest relaxation and the real-time music video, Surge, the lowest relaxation.

As the three environments did not have aversive stimuli and the fair environment provided a positive disposition to the participants, all three environments had a similar level of valence. Only if one of the environments, for example, had aversive stimuli such as a snake or spider, could we expect negative valence values as observed in other studies that used virtual reality to evaluate emotions [11]. There were also significant differences in presence. The presence was higher in the environment where the arousal was also higher, in fact there is a positive correlation ($r = 0.384$; $p < 0.01$), although in all the environments we verified high levels of presence. In the obtained results, it is verified that the dimension valence is positively related to the concentration. These data are in line with other studies [12, 36, 37].

Not rejecting limitations in the study, the data obtained can be useful as guidelines in the development of environments in different contexts (work, leisure, teaching, therapeutic). The creation of environments capable of stimulating users in specific emotional dimensions, which could be relevant to improve performance in a specific task. Can be useful if we think of high-performance sports activities (e.g. athletes, etc.), or at times of decision making (e.g. court judges, etc.). Also the creation of environments capable of inducing states of relaxation could contribute to the development of new strategies of stress coping using virtual reality.

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