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TITLE:

Assessing brain activations associated with emotional regulation during virtual reality mood induction procedures

ABSTRACT:

Emotional Regulation Strategies are used by people to influence their emotional responses to external or internal emotional stimuli. The aim of this study is to evaluate the brain activations that are associated with the application of two different emotional regulation strategies (cognitive reappraisal and expressive suppression) during virtual reality mood induction procedures. We used Emotiv EPOC to measure the brain electrical activity of participants while sadness is induced using a virtual reality environment. We monitored 24 participants, who were distributed among three experimental groups: a control group, a cognitive reappraisal group and an expressive suppression group. In the control group, we found significant activations in several right frontal regions that are related to the induction of negative emotions'. We also found significant activations in the limbic, occipital, and parietal regions in the emotional regulation groups. These regions are related to the application of emotional regulation strategies. The results are consistent with those shown in the literature, which were obtained through clinical neuroimaging systems.

KEYWORDS:

Emotional Regulation Strategies; EEG; Emotiv EPOC; Virtual Reality; Sadness; sLORETA

1. INTRODUCTION

Emotional Regulation (ER) is a surging field of great interest for health sciences in general and for psychology and education in particular. There are several reasons for this, but one of the most important ones is the central role that emotions play in day-to-day living. In the words of Chambers et al. (2009), ER can be generally defined as "the process of modulating one or more aspects of an emotional experience or response". This process has an impact on the intensity, duration, and expression of emotions (Gross et al., 2007). ER is therefore considered to be an important factor influencing virtually all aspects of life, including our physical and mental health, maintenance of social relationships, and adaptation to new daily situations. This reinforces ER as a perfect candidate in prevention measures for psychological problems. Numerous scientific studies indicate that a lack of adequate ER is highly linked to the occurrence of numerous mental and physical health problems, including borderline personality disorders, depression (Ochsner et al., 2007), anxiety disorders, social interaction or adaption problems, addictions, violent behavior, and other disruptive behaviors (Davidson et al, 2000; Gross, 2002).

As Gross et al., 2007 defined in their "modal model" of emotion, the generation of emotions is a special sequential process (situation-attention-appraisal-response) that occurs over time. According to this "modal model", many of the psychopathological traits are due to deficiencies in one or more stages of these emotion-generative processes. In other words, a psychopathological trait may be due to not knowing how to change or select a situation, which could lead to a strong positive or negative emotion. It may also be due to not being able to focus attention from emotionally harmful activities to other less harmful activities. Finally, deficiencies or defects in the processes of reevaluation of emotional situations or modulation of emotional responses to more socially accepted ones are possible causes of psychopathological traits (Werner et al., 2010). Therefore, adaptive ER is the selection and implementation of emotional regulation strategies (ERS) that are adapted to the different stages of this emotion-generative process, so that an emotional experience can be processed as a healthy emotional experience (Mennin et al., 2007). These ERS could also provoke simultaneous changes in cognitive and physiological processes (Chambers et al 2009). Thus, the association between emotional regulation and personal adjustment, social competence, and cognitive function suggests that the development of ERS has significant personal consequences.

ERS enable people to influence the emotions they have, when they have them, how they experience them, and how they express them. ERS can be automatic or controlled and conscious or unconscious. ERS should be differentiated based on when they have their first impact on the emotion-generation process. ERS are able of being involved at one or more stages of this process. According to the model of emotion regulation presented by Gross et al. (2003), ERS can either be antecedent-focused or response-focused. Antecedent-focused strategies refer to the manipulation of the stages previous to the creation of an emotion, which involves the selection and modification of the situation, the control of attention deployment, and the cognitive reappraisal of the situation by seeking to modify the emotional response before it manifests itself. In contrast, response-focused strategies refer to the manipulation of the emotional response once it has been generated (Chambers et al 2009). Both the physical and psychological implications will be different depending on the strategy used.

Despite the fact that there are diverse ERS, in this study we focus on one antecedent-focused strategy (Cognitive Reappraisal) and one response-focused strategy,

(Expressive Suppression). Cognitive Reappraisal (CR) is a cognitive-linguistic strategy that changes the trajectory of the emotional response by assigning a non-emotional meaning to a situation. On the other hand, the Expressive Suppression (ES) is a strategy that is directed towards inhibiting behaviors that are associated with emotional responding (e.g., controlling facial expression or gestural response due to an emotion (Goldin et al., 2008)). Numerous studies have identified the efficacy of CR strategies in modulating and decreasing the impact of intense negative emotions without generating high psychological and physiological responses (Chambers et al., 2009). In contrast, the excessive use of ES strategies is linked to the appearance of emotional disorders, such as depression (Gross et al., 2003).

Currently, there are tools based on new technologies that are starting to be applied to train ER. For example, Playmancer (Moussa et al., 2009) is a European Project that developed a system that was capable of multimodal emotional recognition. It combined a serious game with virtual reality for ER training for the purpose of treating psychological and behavioral disorders. Another project is REPLAY (Ibañez et al., 2010), which evaluated ways of improving the emotional involvement and sense of presence of the players in a virtual reality environment and training them in ER strategies through the proper selection of content and use of exocentric avatar-based interfaces and technologies, such as low-cost tracking.

Another way of training ER strategies is through the use of new interactive technologies that allow having influence on certain aspects of the ER training process. This influence can be achieved through Virtual Reality (VR). VR is a technology that allows us to create environments where we can interact with any object in real time and that has been widely used for training and learning purposes. The devices and techniques for navigation and interaction through virtual experiences have improved greatly, thus providing a more natural and motivating learning experience. Moreover, VR provides benefits such as a high capability for immersion and persuasion. All of these features allow us to use VR in studies of emotional evaluation and intervention. This is evident in previous studies that have demonstrated the usefulness of VR in psychological intervention for various psychological disorders such as claustrophobia (Botella et al., 1998), fear of flying (Baños et al., 2002; Botella et al. 2004) or stress (Baños et al., 2011).

In order to assess emotional regulation, we must have tools that allow us to evaluate and assess the ERS that subjects apply in the context of emotional experiences. The traditional methods that are used include subjective questionnaires, which ask the patients about how they experience and manage their emotions. The Emotion Regulation Checklist (Shields et al., 1997) and The Emotion Regulation Questionnaire (Gross et al., 2003) are good examples of ER questionnaires. Although these questionnaires have proven to be very useful, they have limitations that make them not very suitable for certain groups that are especially reluctant to be assessed. Moreover, when these questionnaires are used in combination with virtual environments, it may only be possible to use them before or after the experience, but never during the virtual exposure without interrupting it. The use of other kinds of techniques, such as physiological measures, can help to overcome these limitations and complement the information obtained with the questionnaires. Gross (1998b) analyzed the influence of the application of ERS on heart rate during a stressful interview. The students that applied an ERS showed a greater heart rate than the students that did not apply an ERS. Campbell-Sills et al. (2006) compared the physiological effects of two ERS

(suppression and acceptance) in individuals with emotional disorders. This experiment consisted in a negative emotional induction using a film clip while the subjects applied one of the two strategies. It was observed that the acceptance group showed less negative emotion than the suppression groups in the recovery period after the film. Moreover, there was an increase in the heart rate of the suppression group, and a decrease in the heart rate of the acceptance group.

Other tools that can be used to supplement the information supplied by traditional methods are brain activity measures. Increasingly, affective studies are using brain activity measures to improve understanding of the underlying mechanisms of affective states. Brain activity can be assessed by means of different neuroimaging techniques, such as functional magnetic resonance imaging (fMRI) or Positron Emission Tomography (PET). Several neural structures that intervene in ER processes have been identified using fMRI (Phillips et al., 2008). The majority of these structures were localized in the limbic and frontal regions. The frontal region is reciprocally connected with other subcortical limbic regions, which have an influence on the different steps of the ER process (Stein et al., 2007). The prefrontal cortex (PFC), cingulate cortex, and amygdala have been shown to have influence on the responses to emotional stimuli (Johnstone et al., 2007; Wager et al., 2008; Ochsner et al., 2007).

More specifically, the neural structures involved in emotional processing form two systems (the ventral emotion system and the dorsal emotion system) that have a role in the decrease of negative emotions (Ertl et al., 2013). These structures form a complex network that is responsible for processing responses to emotional events (Ochsner et al., 2005). In turn, they involve the ventromedial prefrontal cortex, the dorsolateral prefrontal cortex, the orbitofrontal cortex, amygdala, insula, hippocampus, and cingulate cortex (Davidson, 2000; Ertl et al., 2013; Phillips et al., 2008; Ochsner et al., 2005; Suveg et al., 2007). These neural networks play an important role during voluntary or involuntary ER processes as well as in the support to brain regions that are involved in cognitive processes (Phillips et al., 2008; Rubia et al., 2000; Marsh et al., 2006).

In spite of the fact that neuroimaging tools such as fMRI have many advantages (including their high spatial resolution and their ability to detect sub-cortical areas) these techniques do not offer a direct measurement of neural activity (Ertl et al., 2013) and their use combined with navigation in VR imposes many restrictions. A complementary tool to fMRI that has been used in many studies to evaluate brain activity is the Electroencephalogram (EEG), which allows electrical brain activity to be measured in a non-invasive way with a temporal resolution of milliseconds. This makes it possible to analyze all of the fluctuations of the EEG signal that occur in subjects when they are feeling an emotion.

The EEG is a technique that is easily combinable with virtual environments for ER training since it does not impose restrictions on the virtual stimulus to be presented in this study, as occurs with other neuroimaging techniques. In this regard, previous studies consider the use of EEG to be a useful instrument for assessment in ER studies. The important role of the prefrontal cortex for ER has been widely evaluated (Johnstone et al. 2007; Wager et al., 2008; Ochsner et al., 2007). For example, Dennis et al. (2010) observed that the increase of EEG frontal activity was linked to the effective implementation of ER strategies during an emotional induction of sadness and fear.

An additional factor to be considered when evaluating the possibilities of combining EEG monitoring with VR is the emergence of new portable EEG devices that allow

EEG signals to be captured wirelessly and in a more comfortable way. Since these EEG devices are more portable, more ergonomic, less invasive, and more economical, they provide an easy arrangement for emotional studies as well as a significant reduction in cost and time. Emotiv EPOC (Zhang et al., 2010) is an example of a portable EEG device that has recently been used in multi-disciplinary studies and whose effectiveness has been tested (Khushaba et al., 2012; Khushaba et al., 2013). In previous studies, our team analyzed the Emotiv EPOC signal that is measured during different immersion experiences (Clemente et al., 2014) during a positive emotional induction with images from the IAPS system (Rodriguez et al., 2013b) and during a negative mood induction by means of a VR environment (Rodriguez et la., 2013a). This analysis demonstrated the usability of these devices.

Based on these studies and the fact that the influence on brain activations of different ERS applied during a virtual reality mood induction procedure has not yet been directly evaluated, the goal of the present work is to compare brain activity at rest after the application of different ERSs during a negative mood induction in a VR environment. To do this we use a virtual park that was designed and validated for the induction of sadness (Baños et al., 2006) as the virtual reality mood induction procedure in three different experimental groups: the application of a CR strategy, the application of an ES strategy, and the application of no ERS (the control group (CG)). We expect the sadness induction to have an influence on brain areas that are related to the emotion of sadness in the CG group. However, we expect to observe different activations in the CR and ES group, which are related to the emotional regulation that has been applied and not to the pure sadness induction. A wireless portable EEG device is used to evaluate the differences in brain activity that are related to the ERS applied in each condition.

2. MATERIAL AND METHODS

2.1. *Participants*

For the study, 27 healthy participants (14 men and 13 women) participated voluntarily in this experiment; they were divided into three groups of 9 participants each. Three participants (one from every group) were excluded from the analyses due to poor quality EEG recording, leaving a final sample size of 24 participants (12 men and 12 women). The participants were between the ages of 19 and 36 (M=23.36; SD=3.01). All of the participants gave their informed consent prior to their inclusion in the study. All of them had normal or corrected-to-normal vision. The experiments were conducted in a laboratory inside the LabHuman Institute.

In compliance with ethical guidelines, before beginning the study, an Inventory for Measuring Depression (BDI) questionnaire was completed by the participants (Beck et al., 1961). The BDI results were obtained immediately so that depressive participants could be excluded (subjects with a score above 17). None of the participants were excluded from the study (M=4.89, SD=4.022).

2.2. *Instruments*

Two types of instruments (psychological and physiological) were used in this study to measure the participants' experience during the exposure session.

2.2.1. Psychological Instruments

In order to evaluate their emotional states the participants had to complete two questionnaires, the Visual-Analogue Scale (VAS) and the Positive and Negative Affect Schedule (PANAS) before and after the EEG session.

- The VAS questionnaire consists of a 7-point Likert scale that evaluates the current emotional state of participants in terms of their level of joy, sadness, anxiety, and relaxation. The measure was applied both before and after the virtual experimental session (Gross et al., 1995).
- The PANAS questionnaire consists of two 10-item scales that allow the positive affect factor and the negative affect factor to be measured (Watson et al., 1988; Watson et al., 1998). These factors are the most general ones that describe affective experiences. They are calculated by adding the scores for positive items (PANAS-positive) and negative items (PANAS-negative). The PANAS scale ranges from slightly (1) to extremely (5) on a 5-point scale. This measure was applied both before and after the virtual experimental session.

2.2.2. Physiological Instrument: Emotiv EPOC-based EEG data collection

The Emotiv EPOC is a low-cost EEG device that incorporates 14 channels of EEG data and a gyroscope measure. The EEG channel names are based on the International 10-20 system and are located at the positions AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4 (**Figure 1**). Two electrodes located just above the participants' ears (CMR/DRL) are used as references, one for each hemisphere of the head. Internally, Emotiv EPOC has a sample frequency of 2048 Hz which is down-sampled to 128 Hz before transmitting to a computer via Bluetooth. Prior to use, all felt pads on top of the sensor have to be moistened with a saline solution (Khushaba et al. 2012). The Emotiv device was selected because of its low cost and portability, so the study could be performed without any interference in the virtual environment.

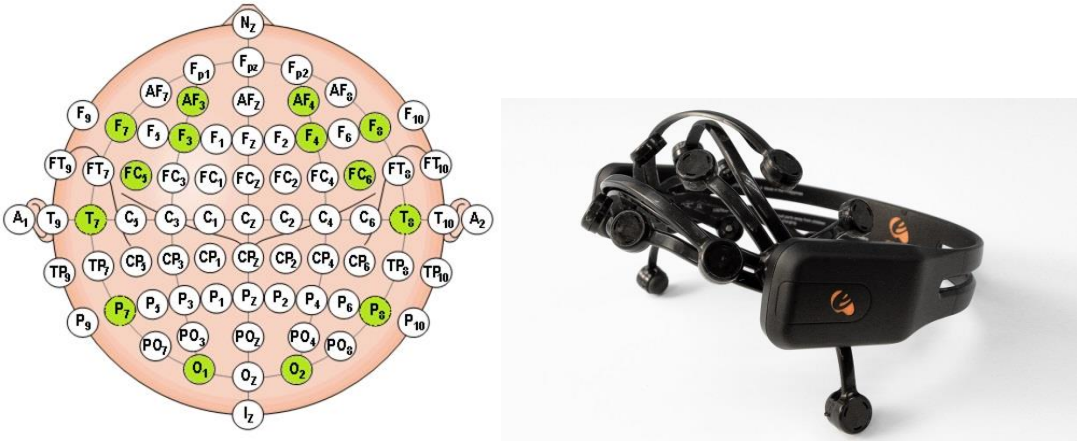

Figure 1. A) Emotiv EPOC electrode positioning. B) Emotiv EPOC device.

2.3. ***Mood Induction***

A virtual reality environment was designed to induce a negative mood (sadness) in the participants. Brainstorm eStudio 11 software (Brainstorm Multimedia, Madrid, Spain) was used as the graphic engine to create the virtual environment. The Python programming language was chosen for its flexibility, which makes it suitable for the purpose of this study.

This virtual environment was composed of a virtual park that has a natural and urban atmosphere that would be easy to find in any real city. This park has trees, flowers, water, urban furniture, a summer open-air cinema and a bandstand in the center (Figure 2). In order to induce a sad mood in the participants while they navigated through the park, different traditional elements to induce emotions were included: music (Sutherland et al., 1982), Velten self-statements (Velten, 1968) plus pictures (selected from the International Affective Picture System IAPS, Lang et al., 2005) and a movie (Gross et al., 1995). This virtual park had already been used in previous studies by our group in order to show that virtual environments can be used as an effective mood-induction procedure (Baños et al., 2006).

Figure 2. Captures of the virtual environment

Before virtual navigation began, the participants had to listen to a short explanation about the virtual emotional experience. A sad woman's voice was used to guide the user through the different sections of the park. At the beginning, the participants were asked to freely explore the park while a piece of "Adagio for Strings-Choral" by Samuel Barber was heard. After that, the voice asked them to go to the bandstand, where the words in Velten statements appeared in random word order and the participants had to put in the correct order to form a sentence. The contents of the statements were written in the first person, such as: "Life seems sad and senseless to me", "I make people unhappy", or "I have no future". Then, the participants had to choose the picture that best represented the meaning of the sentences from four options. This cycle was repeated five times. The IAPS pictures included sad scenes such as children in combat

zones, drug addicts, or funerals. Finally, the participants navigated the virtual park freely until the voice asked them to watch an excerpt of the movie "The Champ" in the open-air cinema.

This virtual park was shown on a 4 x 2 meter retro-projected screen and the participants were able to navigate through the environment using a wireless pad (Logitech Wingman Cordless Rumblepad Gamepad; Logitech, Fremont, CA, USA) at a distance of 3.5 m from the screen (**Figure 3**).

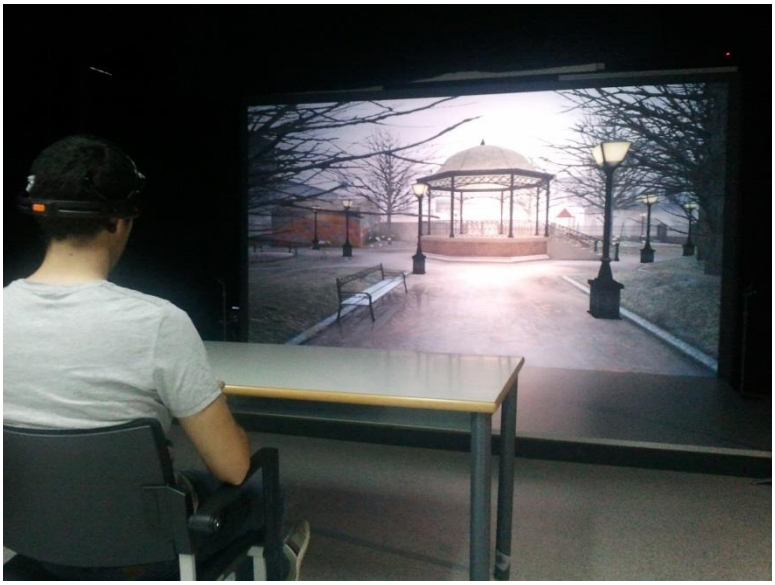

Figure 3. A participant navigating through the virtual park

2.4.***Experimental Design***

The experimental design for this study (Rey et al., 2012) is described below.

The participants spent approximately one hour in the laboratory and completed a series of questionnaires before and after the exposure session. To evaluate pre- and post-induction sadness, the participants completed both the VAS and PANAS questionnaires both at the beginning of the study and then again after the virtual mood induction procedure.

Following the initial questionnaire period, the participants entered a dark room where the mood induction was going to take place. Then, with the help of the researcher, the participants had to practice how to move and interact with the environment in a specifically designed training environment. Afterwards, an Emotiv EEG device was placed on the participant's head by the experimenter. The subjects were separated into three experimental groups, each of which received instructions to apply a different regulation strategy during the virtual exposure. These instructions were adapted to the language and context of the study from the instructions used by Gross (1998a). The Cognitive Reappraisal group (CR) received instructions to apply cognitive evaluation strategies during the induction (i.e., the participants had to navigate through the virtual environment carefully, but they had to reflect on what they were feeling with the intention of applying to it a non-emotional meaning). The Expressive Suppression group (ES) was told to control their expressive responses to the induced mood (i.e., the

participants had to control their external emotional responses to the virtual emotional induction generated so that anyone who was watching the participants would not be able to know their affective state). Finally, the CG did not receive any specific instructions to regulate their emotions. The EEG device was synchronized with the experimenter's computer and the EEG data was recorded throughout the entire virtual exposure.

Before the virtual exposure, two minutes and thirty seconds of resting EEG activity were recorded (BL1). Afterwards, the virtual induction of sadness started. At the end of the virtual induction, two minutes and thirty second of resting EEG activity were recorded again (BL2).

Finally, the participants were invited to watch a film to induce a positive mood in them before finishing the experiment. The film used was an excerpt of the movie "Singing in the Rain".

2.5.*Data Analysis*

In order to compare the scores between the CG, CR, and ES groups regarding the psychological information that was collected in the test questionnaires (VAS and PANAS), a Wilcoxon Signed-Rank test was applied. All of the analyses were performed using the SPSS 17.0 application (IBM Corporation, Somers, New York, USA) application with the significance level set at 0.05.

The EEG recordings were analyzed off-line using custom software written in MATLAB R2011B (MathWorks, Inc). This software is based on the EEGLAB library (Delorme et al., 2004), which provides many functions that can be used to pre-process and clear the EEG-data. All the recorded EEG epochs were checked for artifacts (e.g., electrooculogram (EOG) and muscle (EMG) activity, eye blinks, electrical and baseline noise).

The preprocessing of the recorded EEG was applied to the data corresponding to two and a half minutes before starting the baseline study (BL1) and two and half minutes after completing the virtual baseline study (BL2). The preprocessing of the EEG signal started with a detrending removal to eliminate the DC offset in the EEG. This was followed by a linear band pass filter (0,5-45 Hz) that removed the effect of the 50 Hz noise and higher frequency artifacts (Khushaba et al., 2012; Kober et al., 2012; Khushaba et al., 2013).

Then the EOG and EMG artifacts were detected and deleted using the ADJUST method (Mognon et al., 2011), which is based on Independent Component Analysis (ICA). ADJUST is a semi-automatic toolbox of EEGLAB that detects Independent Components with possible artifacts generated by EOG or EMG and advises their elimination. Other artifacts were removed manually using ICA analysis.

The activated brain areas were estimated through the sLORETA tools(standardized low-resolution electromagnetic tomography) (Frei et al., 2001; Pascual-Marqui et al., 1994; Pascual-Marqui et al., 1999; Esslen et al., 2004). The sLORETA tools solve the EEG inverse problem and localize the EEG activation source with a minimum low localization error to within 1 voxel resolution on average (Pascual-Marqui et al., 2002; Paquete et al. 2009). They also provide a realistic estimation of activation in the whole brain in a standard 3D brain map. The whole brain was analyzed using voxel-wise t-test to examine the difference between the BL1 and the BL2 condition for each group

individually on the theta and alpha bands. Then, the same voxel-wise t-tests were used to compare the BL2 condition among the three groups. All of the analyses were performed with the significance level set at 0.05.

3. RESULTS

3.1. *Questionnaire Results*

Post-hoc analyses based on Wilcoxon signed rank tests were performed on the VAS variables (Joy, Sadness, Anxiety, and Relaxation) and the PANAS variables (PANAS-positive and PANAS-negative) with significant level $p<0.05$. For the CG group, there were no significant differences between the two conditions for any variables. For the CR group, there were significant differences between the BL1 and BL2 conditions for the VAS-joy ($Z=2.232$; $p=0.026$). For the ES group, there were significant differences between the BL1 and BL2 conditions for the VAS-joy ($Z=2.271$; $p=0.023$), VAS-sadness ($Z=-2.232$; $p=0.026$) and PANAS-positive ($Z=2.383$; $p=0.017$). All of the results are shown in **Table 1**.

		BL1	BL2	Z (BL1>BL2)	P
VAS-joy	*CG*	4.50 ± 0.54	4.25±0.59	0.000	>0.05
	CR	5.13 ± 0.30	3.88±0.55	**2.232**	**0.026**
	ES	4.88 ± 0.40	3.63±0.32	**2.271**	**0.023**
VAS-sadness	*CG*	2.25 ± 0.45	2.38±0.57	0.000	>0.05
	CR	2.13 ± 0.30	2.88±0.48	-1.656	0.098
	ES	1.88 ± 0.48	3.50±0.63	**-2.232**	**0.026**
VAS-anxiety	*CG*	1.13 ± 0.13	1.38±0.38	-0.447	>0.05
	CR	1.75 ± 0.37	1.75±0.37	0.000	>0.05
	ES	2.13 ± 0.40	2.63±0.63	0.850	>0.05
VAS-relax	*CG*	5.00 ± 0.46	5.00±0.33	0.000	>0.05
	CR	4.63 ± 0.57	4.63±0.53	-0.106	>0.05
	ES	3.38 ± 0.18	3.38±0.57	0.106	>0.05
PANAS-positive	*CG*	25.38 ± 3.61	21.88±3.06	-1.527	>0.05
	CR	31.75 ± 2.10	28.38±3.77	1.192	>0.05
	ES	29.50 ± 2.93	22.00±3.07	**2.383**	**0.017**
PANAS-negative	*CG*	12.63 ± 0.87	12.63±1.09	0.000	>0.05
	CR	13.38 ± 1.19	13.25±1.16	0.316	>0.05
	ES	14.13 ± 1.47	17.38±3.13	-1.103	>0.05

Table 1. The VAS and PANAS responses to the questionnaires for each group (mean score and standard error of the mean) and the results of the Wilcoxon Signed-Rank Test for the comparison of the VAS and PANAS results between the BL1 and BL2 experimental conditions.

3.2. *EEG Results*

For the CG group, the comparison between the BL1 and BL2 moments using the voxel-wise t-test for the theta and alpha band revealed significant differences in the theta band (4-7 Hz) and alpha-band (8-12 Hz) for $p<0.05$. Theta band power decreased in the BL2

condition in the right uncus (BA 20) and the right temporal lobe (BA 20), which indicates decreased activity in these regions during the BL2 condition. However, in the alpha band, power decreased in the BL2 condition in the frontal lobe (BA 47), which indicates increased activity in these regions during the BL2 condition. **Figure 4** shows for the BL1>BL2 contrast in the theta band and the alpha band can be seen in All the results for this contrast are shown in **Table 2**.

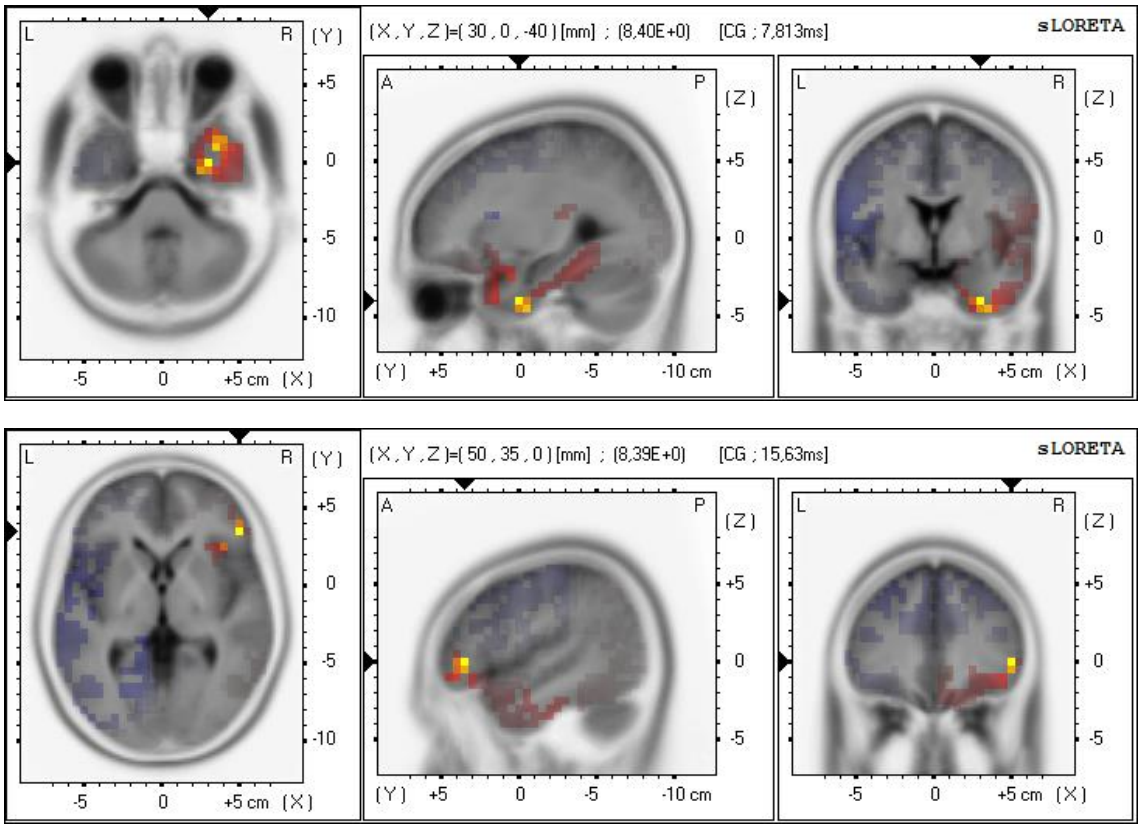

Figure 4. The results for the BL1>BL2 contrast for the CG group. Captures of sLORETA activation for the BL1>BL2 contrast in: (a) Theta band, (b) Alpha group.

For the CR group, the same comparison between the BL1 and BL2 moments (again using voxel-wise t-test for the theta and alpha bands) revealed several significant differences in the theta band for $p<0.05$. Theta band power increased in the BL2 in the cingulate Gyrus (BA 24) and the anterior cingulate (BA 33) for both hemispheres, indicating increased activity in these regions after applying the cognitive reappraisal strategy. **Figure 5a** shows comparison between the results for the BL1<BL2 contrast in the theta band. All the results for this contrast are shown in **Table 2**.

However, even though we did not find any significant results for the ES group, we did find several areas with a trend to significance. For the theta band and left hemisphere, the ES group showed a higher activation ($p>0.05$) in several temporal areas as well as in the precuneus (BA 19). The results for the ES group are shown in **Figure 5b** and **Table2**.

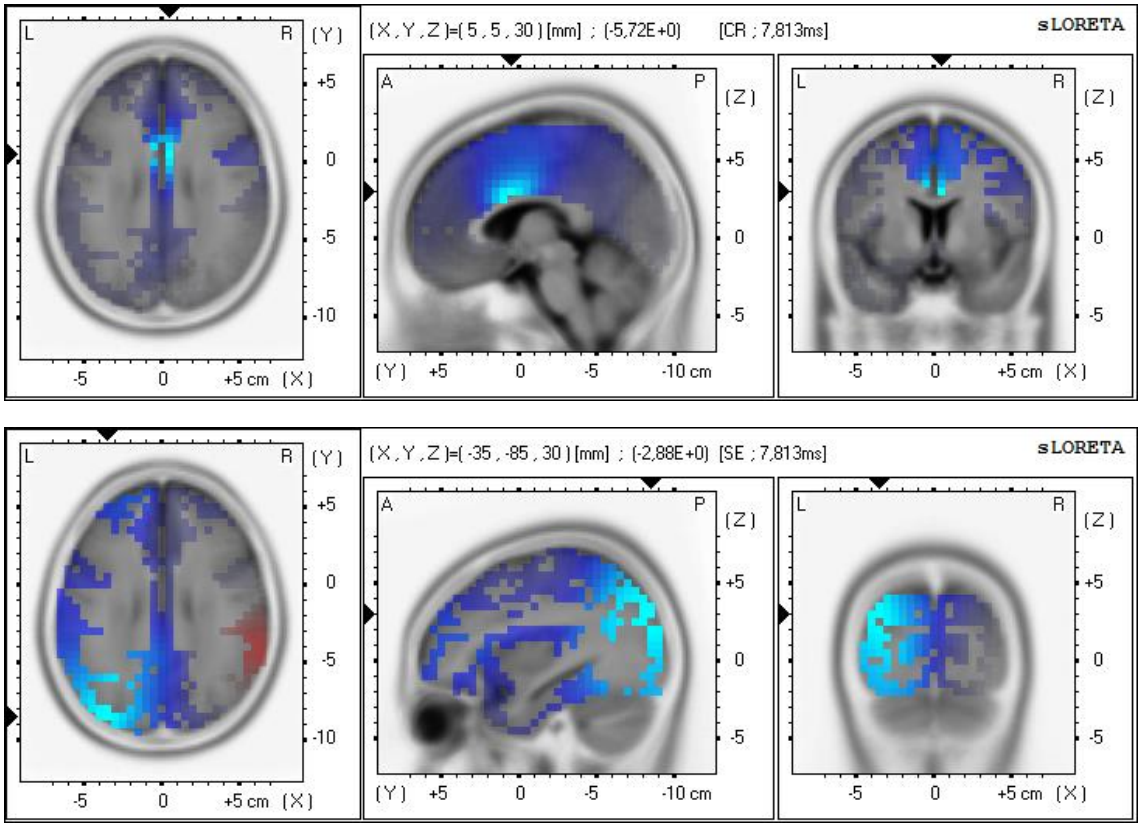

Figure 5. The results for the BL1< BL2 contrast for the CR and ES groups. Captures of sLORETA activation for the BL1< BL2 contrast in theta band for: (a) the CR group, (b) the ES group.

Group	Brain Area	Band	Hemisphere	p
CG	Limbic Lobe; Uncus (BA 20)	Theta	Right	<0.01
CG	Limbic Lobe; Uncus (BA 20, 36)	Theta	Right	<0.05
CG	Temporal Lobe; Superior Temporal Gyrus (BA38)	Theta	Right	<0.05
CG	Temporal Lobe; Middle Temporal Gyrus (BA38)	Theta	Right	<0.05
CG	Temporal Lobe; Inferior Temporal Gyrus (BA 20)	Theta	Right	<0.05
CG	Frontal Lobe; Inferior Frontal Gyrus (BA 47)	Alpha	Right	<0.05
CG	Frontal Lobe; Middle Frontal Gyrus (BA 47)	Alpha	Right	<0.05
CR	Limbic Lobe; Cingulate Gyrus (BA 24)	Theta	Right // Left	<0.05
CR	Limbic Lobe; Anterior Cingulate (BA 33)	Theta	Right // Left	<0.05
ES	Temporal Lobe; Angular Gyrus (BA 39)	Theta	Left	>0.05
ES	Parietal Lobe; Precuneus (BA 19)	Theta	Left	>0.05
ES	Temporal Lobe; Middle Temporal Gyrus (BA 19)	Theta	Left	>0.05

Table 2. Comparison of the results for the CG (BL1>BL2 contrast), CR (BL1< BL2 contrast), and ES (BL1< BL2 contrast) groups.

Furthermore, the results obtained using the voxel-wise t-tests when comparing the BL2 condition between the CG and CR groups showed significant differences in several areas in the theta band in the right hemisphere. In the CR group, theta power was significantly higher on the lingual gyrus (BA 18), on the cuneus (BA 23) with $p<0.01$, and significantly higher on the precuneus (BA 31) with $p<0.05$.This indicates activations in these regions for the CR group. **Figure 6 shows** this comparison for the BL2 condition. All of the results for this contrast are shown in **Table 3**.

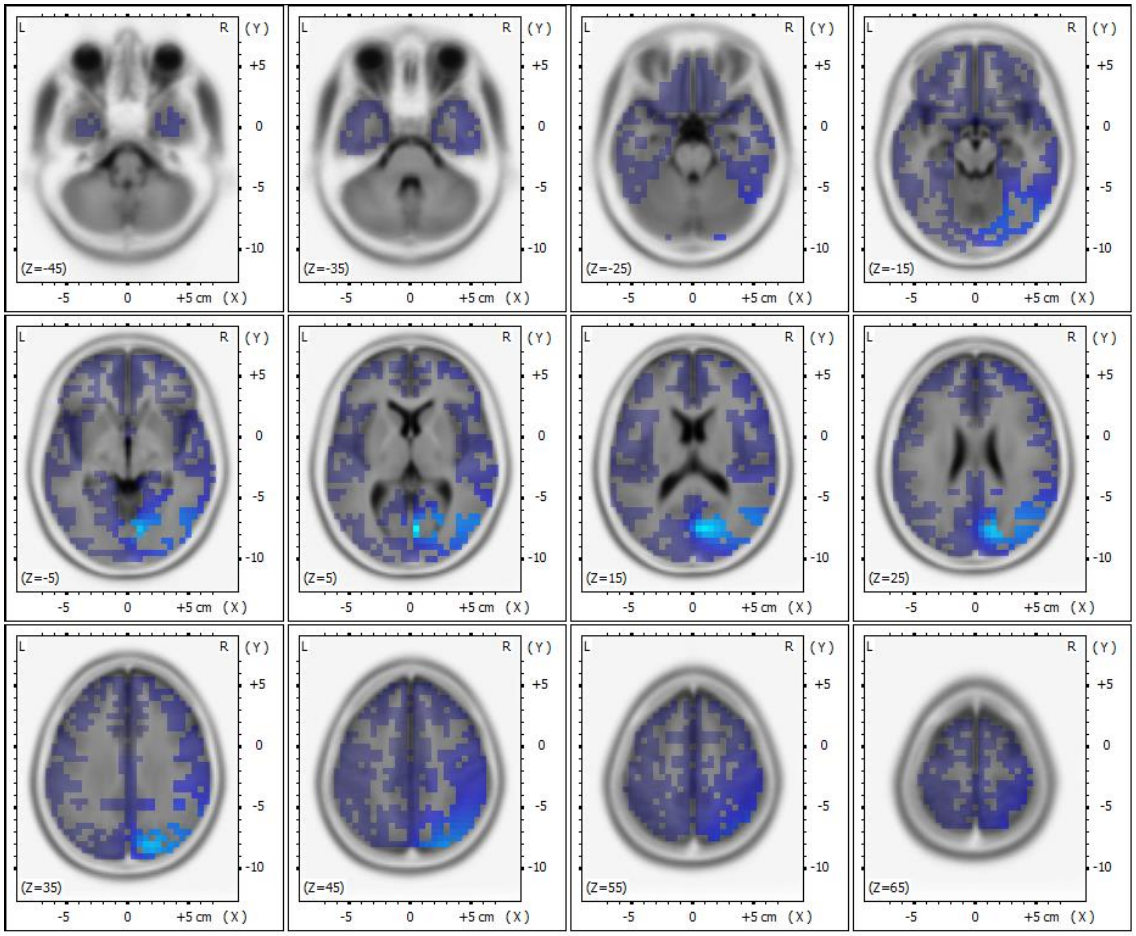

Figure 6. The results for the CG<CR contrast for the BL2condition. Captures of sLORETA activation for the CG<CR contrast in theta band.

With regard to the comparison of the BL2 condition between the CG group and the ES group, a significant activation was shown for the ES group in the precuneus (BA 7, 31), superior parietal lobule (BA 7), cuneus (BA 7) with $p<0.05$, and cingulate gyrus (BA 31) with $p<0.10$ in theta band. **Figure 7** shows this contrast. All of the results for this contrast are shown in **Table 3**.

Finally, we did not find any significant results for either the comparison in the BL2 condition between the CR and ES group or for the comparison in the BL1 condition among all of the groups.

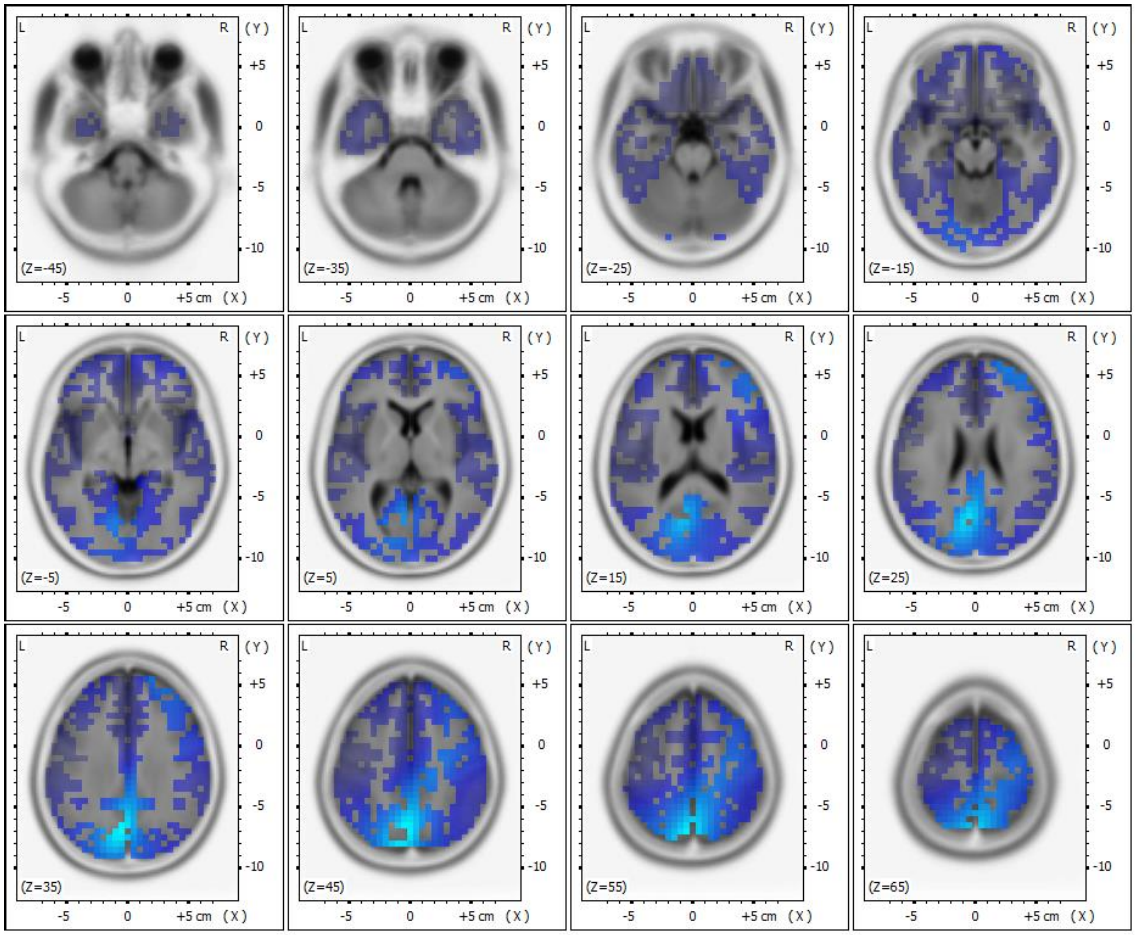

Figure 7. The results for the CG<ES contrast for the BL2 condition. Captures of sLORETA activation for the CG<ES contrast in theta band.

Condition	Brain Area	Band	Hemisphere	p
CG<CR	Occipital Lobe; Lingual Gyrus (BA 18)	Theta	Right	<0.01
CG<CR	Occipital Lobe; Cuneus (BA 23)	Theta	Right	<0.01
CG<CR	Occipital Lobe; Lingual Gyrus (BA 18, 19)	Theta	Right	<0.05
CG<CR	Occipital Lobe; Cuneus (BA 7, 17, 18, 19, 30)	Theta	Right	<0.05
CG<CR	Parietal Lobe; Precuneus (BA 7, 19 31)	Theta	Right	<0.05
CG<CR	Occipital Lobe; Middle Occipital Gyrus (BA19)	Theta	Right	<0.05
CG<CR	Temporal Lobe; Middle Temporal Gyrus (BA 37, 39)	Theta	Right	<0.05
CG<CR	Limbic Lobe; Posterior Cingulate (BA 18, 30, 31)	Theta	Right	<0.05
CG<CR	Occipital Lobe; Superior Occipital Gyrus (BA19)	Theta	Right	<0.05
CG<CR	Parietal Lobe; Superior Parietal Lobule (BA 7)	Theta	Right	<0.05
CG<ES	Occipital Lobe; Cuneus (BA 7)	Theta	Left	<0.05

CG<ES	Parietal Lobe; Precuneus (BA 7)	Theta	Left // Center	<0.05
CG<ES	Parietal Lobe; Superior Parietal Lobule (BA 7)	Theta	Left	<0.05
CG<ES	Limbic Lobe; Cingulate Gyrus (BA 31)	Theta	Left //Center //Right	<0.10
CG<ES	Limbic Lobe; Posterior Cingulate (BA 31)	Theta	Left	<0.10

Table 3. Comparison of the results for the BL2 moment for the CG, CR, and ES groups.

4. DISCUSSION

This study evaluates the evolution of human brain activity when two different Emotional Regulation Strategies (ERS) were applied during exposure to a virtual reality (VR) environment that was designed to induce a sad mood. The use of an ERS based on a cognitive-linguistic strategy (Cognitive Reappraisal, CR) and an emotional response strategy (Expressive Suppression, ES) were compared with a Control Group (CG), where only a sad mood was induced and no specific ERS was applied. The purpose was study the changes in the brain activity due to the ERS applied using an Emotiv EPOC headset. The main findings and their implications are discussed below.

The first hypothesis in the study assumed that the virtual environment would induce sadness in participants and that this would be reflected in the brain areas related to the emotion of sadness in the CG group. This hypothesis was confirmed.

We analyzed the subjective and objective results related to sadness induction in the participants for the CG group. Even though the subjective VAS and PANAS measurements did not show any significant results regarding the induction of sadness, the EEG analysis showed evidence of a negative mood induction in the participants. More specifically, the participants had a significant increase in brain activation in the right inferior frontal gyrus and the right middle frontal gyrus for the alpha band. According to Baumgartner et al. (2010), these frontal areas are a major part of a fronto-parietal attention network, which works as a target detection and an alarm system to new stimuli that could appear when we are engaged in other processes that need all of our attention. Furthermore, the inferior frontal gyrus is also known to play an important role in negative emotional processes such as sadness (Boyatzis et al., 2012). In this respect, Vytal et al. (2010) showed a strong implication of the right inferior frontal gyrus in sad emotions when they compared the brain activation of sadness and happiness.

Apart from the activation in the alpha band, we have also found significant negative activations in the right uncus (Limbic Lobe) and the right inferior temporal gyrus, middle temporal gyrus, and superior temporal gyrus. The activation in these right temporal regions are normally related to the emotion of happiness. For example, through a meta-analysis, Vytal et al. (2010), found a consistent activation of the right superior temporal gyrus when happiness was compared with sadness, anger, fear, and disgust. Killgore et al. (2004) showed a significant activation of the right inferior temporal gyrus while the participants were looking at happy faces. Therefore, the negative activations that were measured in the temporal lobe may be linked to a decrease in happiness emotions when sadness was induced in the participants.

With regard to the negative activation in the right uncus, we know that the function of the uncus in the parahippocampal gyrus plays an important role in the recognition of scenes (Epstein et al., 1999) and the sense of presence (Clemente et al., 2014). We hypothesize that this negative activation of the uncus could be linked with familiarity of the virtual environment (Epstein et al., 1999). However, this hypothesis should be studied in future works.

The results for first hypothesis indicate that a negative mood was induced in the participants in the CG group when they navigated through the virtual park.

The second hypothesis assumed that the ERS would have brain activations in areas related to the ER in the participants of the emotional regulation groups (CR and ES). This hypothesis was partially confirmed for both of the emotional regulation groups.

For the CR group, we found significant activations for the theta band in the cingulate gyrus and the anterior cingulate, which are both on the limbic lobe. This is a relevant result because these areas play an important role in emotional regulation during active reappraisal, (Ochsner et al., 2005; Kalisch et al., 2006), emotional stimulus processing (Esslen et al. 2004, Bush et al., 2000), modulation of emotional responses to cues (Ray et al., 2005; Phillips et al., 2003), and in other functions such as episodic memory function (Paus et al., 1998) and learning and spatial attention (Baumgartner et al., 2006). There are also studies where the increased activation of some parts of the cingulate cortex has been used as a possible predictor for an antidepressant treatment (Saxena et al., 2003). In this regard, a recent study (Smoski et al., 2013) provides evidence that increased anterior cingulate activation could be related to an improvement in emotional regulation functions in individuals that are recovered from an episode of depression. This evidence would be close to our results, which would therefore suggest that our participants were able to apply a CR strategy during the study.

On the other hand, the analysis of the brain activation in the ES group did not show any significant results. Despite this, we found brain activations on the precuneus and the angular gyrus in the participants during the application of the expressive suppression strategy. These areas are known for being related to the sense of self-awareness or self-consciousness (Kjaer et al., 2002; Lou et al., 2004) and the sense of presence and navigation (Clemente et al., 2014). The brain activation of these areas could be linked to the fact that the participants (who applied expressive suppression strategy) had to be conscious of the negative perceived emotion in order to inhibit the external behaviors that are associated with a possible emotional response.

The analyses of questionnaires showed results that were contradictory to those obtained from the EEG for both emotional regulation groups. More specifically, the participants had a significant decrease in the emotion of joy (VAS-joy) in both groups. There was a significant increase in the emotion of sadness (VAS-sadness) in the ES group only. A significant decrease in positive emotion (PANAS-positive) was also observed in the ES group. In our opinion, the reason for the variations reflected in the subjective measurements might be the difficulty of expressing a final emotion by means of questionnaires when the participants performed a conscious emotional regulation strategy. It seems logical for both positive and negative emotions were affected after making the effort to apply an ERS to an emotional induction. This could therefore be evidence of the subjectivity of these questionnaires when they are used in an ER study.

Finally, we analyzed the comparison between the brain activation due to ERS in the ER groups (i.e., CR and ES groups), and the brain activation due to sadness induction in the CG group.

Indeed, the comparison of BL2 between the CG and the CR groups showed a significant activation (CG<CR) in the lingual gyrus and the cuneus (both on the occipital lobe) and in the precuneus. According to the literature, the lingual, cuneus, and precuneus are involved in the visual attention process (Mangun et al., 1998) and the cognitive reappraisal process (Ziv et al., 2013). Therefore, the results suggest that these regions were activated because the participants in the CR group applied an ERS based on cognitive reappraisal.

The results of the comparison of BL2 between the CG group and the ES group showed significantly higher activation (CG<ES) in the precuneus, superior parietal lobule, cuneus, and a trend to significance in the cingulate gyrus for the ES group. According to the literature, these areas play a role in spatial processing, mental rotation tasks and the ego-centric view (Baumgartner et al., 2006, Jordan et al., 2004; Jordan et al., 2001; Gron et al., 2000). Thus, the results obtained in our study could show that, in order not to show any negative emotion, the participants in the ES group were aware of everything that was going on around them.

The present study has some limitations. First, the number of participants in this work is limited. The results should be confirmed with a large population of different age-range and ethnicities. Then we could determine the impact of age and ethnicity on ER and their impact on brain activations. Second, before starting the experimentation, we gave the participants some instructions to help them perform their assigned ERS correctly. Even though these instructions were clear and concise, some participants had difficulty understanding them, which resulted in the need to spend more time explaining the instructions to them. Perhaps it would have been desirable to perform a previous training session for these ERS such as the one Ertl et al. (2013) conducted in their study. This might have had a positive effect on the participants' implication in the experimentation and a positive effect on the perception and regulation of the induced emotion and we might have had higher quality in the neural source localization. Third, no clinic EEG devices were used in this study. Although one the goals of the study was to evaluate the Emotiv EPOC headset in an ER study, it would be interesting to use a professional EEG device with a higher number of electrodes in order to improve the quality of the source localization. Finally, we used a VR environment to induce a specific negative emotion. In the future it might also be worth exploring the scope for inducing other types of emotions such as happiness or anger through VR environments in order to evaluate the Emotiv EPOC headset in different situations.

5. CONCLUSIONS

In summary, the main goal of this study was to evaluate the brain activity due to the application of two emotional regulation strategies when an emotion of sadness was induced by a virtual environment. We measured the EEG signal using Emotiv EPOC for three conditions: a sadness induction condition and two emotional regulation conditions (cognitive reappraisal and expressive suppression). The results show activation in several relevant brains regions that are associated with sadness induction (for the CG group) and that are associated with the application of emotional regulation strategies (for the CR and ES groups). The results were similar to those obtained in previous studies. More precisely, we found activation in the right frontal areas for the

CG related to an induction of sadness (Baumgartner et al., 2010). We also found significant activations in the cingulate, occipital, and parietal areas in the CR group related to the application of a cognitive reappraisal strategy (Phillips et al., 2003; Ziv et al., 2013). However, we did not find conclusive results for the ES group. In spite of the fact that we found brain activations that could indicate that the participants complied with the purpose of the condition and applied the ERS, we did not find any significant activation to confirm this.

In addition, another key implication of this study (though was not an objective of this work) is the fact that all of our findings were obtained through the processing of a temporal measure that was obtained by a low-cost portable EEG tool. The results achieved were similar to those obtained by complex neuroimaging systems. Therefore, we consider that the Emotiv EPOC headset can be used in emotional regulation studies as an objective evaluation tool. Previously, our team had evaluated the usability of the Emotiv EPOC headset in the context of the sense of presence in virtual environment (Clemente et al., 2014) and mood induction using emotional pictures (Rodriguez et al. 2013b) and virtual mood induction procedures (Rodríguez et al., 2013a). With the results obtained in the present work, we have contributed to the evaluating of the usability of the Emotiv EPOC headset in the field of emotional regulation.

This work will allow us to opens up a whole range of possibilities for research and work in a new framework. Future works could evaluate other ways of training ERS based on virtual reality or serious games in order to improve the use of classical ERS training based on instructions. The impact of these new tools in the emotional regulation field could also be evaluated in populations that are especially reluctant to be assessed, such as adolescents. Virtual reality can be useful in improving the engagement of this population in emotional health prevention and treatment programs. Finally, the use of new tools to train different ERS applied to other emotions such as happiness or frustration could also be analyzed in both clinical populations and non-clinical populations.

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