Neuroticism is associated with reduced oxygenation levels in the lateral prefrontal cortex following exposure to unpleasant images

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Abstract: The aim of this study was to explore the prefrontal cortex response to emotional salient stimuli in subjects with high scores in Neuroticism (and low in Sensation Seeking) or high scores in Sensation Seeking (and low in Neuroticism) personality traits, *-called now Neuroticism and Sensation Seeking groups-*. For this purpose, we selected 24 females (mean age: 20; SD: 1.74 years) and assigned them to two different groups according to their extreme score in personality dimensions. Ten pleasant and ten unpleasant pictures from the International Affective Picture System were presented. Neuroticism group showed significant effects for valence at the lateral prefrontal cortex in both brain hemispheres. They showed higher Oxygenation for pleasant pictures, more significantly in the left ($Z = 2.49$, $p = 0.01$) than in the right hemisphere ($Z = 2.19$, $p = 0.03$). The highest differences were registered in ventral optodes. In contrast, Sensation Seeking group did not show significant differences in hemodynamic variables as depending on the valence of the pictures. These data suggest a differential functioning of the lateral prefrontal cortex, mainly the left ventrolateral cortex, in Neuroticism group to pleasant and unpleasant visual stimuli. We hypothesize that if the lateral prefrontal activity is low, it could be the result of an over-activation of the amygdala in response to unpleasant pictures in subjects with Neuroticism or negative emotionality. These activation patterns could be related to vulnerability to emotional disorders.

Key words: Neuroticism, Sensation Seeking, Prefrontal Cortex, fNIRS.

1. **INTRODUCTION**

Neuroticism or negative emotionality is a universal personality trait. People with high Neuroticism are prone to anxiety, depression, worry, mood swings and stress susceptibility. Neuroticism is a central focus in the so-called biologic-factorial personality models [1-3]. Neuroticism is linked to arousability of a reticulo-limbic-cortical system controlling emotion [4]. Gray's theory is linked to sensitivity of brain systems to anxiety and impulsivity personality traits [5]. The brain systems underpinning Neuroticism have profound influences in behavior, controlling the individual ability to learn conditioning and to manage stressful encounters [6]. Sensation Seeking is a dimension of personality defined by the individual's need for sensory stimulation and the level of risk taken for the sake of such stimulation [7]. Both personality dimensions have correlations close to zero or negative [8]. While people high in Neuroticism are emotional and anxious, high Sensation Seeking subjects are impulsive and show a low level of anxiety. People high in Neuroticism are more sensitive to aversive stimuli while high Sensation Seeking subjects are more sensitive to reinforcing or novelty stimuli. In fact, Neuroticism correlated strongly with the Sensitivity to Punishment (SP) associated with the Behavioral Inhibition System (BIS) and Sensation Seeking with the Sensitivity to Reward (SR), related to the Behavioral Activation System (BAS) [9, 10].

Neuroticism and Sensation Seeking are temperamental dispositions related to externalizing and internalizing behavior, connected with psychopathology, and to a common genetic associations associated with emotional disorders [11]. Studies about the nature of Neuroticism and Sensation Seeking were studied in the Zuckerman personality model with pronounced influence in learning, behavior, emotions, and vulnerability to psychopathology [3, 12]. In the personality dimensional models of psychopathology, emotional and behavioral problems are considered to be linked with extreme personality traits. Neuroticism/Negative Emotionality is linked to a personological basis for internalizing behavior, and negative emotionality paired with disinhibition for externalizing behavior [13]. Harm Avoidance (equivalent to Neuroticism) and Novelty Seeking (equivalent to Sensation Seeking) [14] accounted for 26% and 12% of the comorbidity among the emotional disorders [15].

Individual differences in the detection of emotional stimuli and the response to these stimuli, as well as the ability to disconnect from emotional stimuli, are important factors in emotional regulation [16]. Gross

and Jazaieri [17], considering that emotional disorders would appear more during the generation process than during the regulation of emotions. The induction of "bottom-up" processes activates attentional systems and other processes involved in the encoding of emotional properties of stimuli. The induction of "top-down" processes triggers prefrontal regions, associated with higher elaborate cognitive performance [18, 19]. Attention depends on the salience of stimuli and the "top-down" prioritization processing of stimuli [20]. In the presence of threatening stimuli, the activation of subcortical structures, mainly the amygdala, allows a rapid identification [21-23], suggesting that heightened anxiety is associated with reduced lateral prefrontal recruitment that implies a dominance of “bottom-up” sensory driven mechanisms, related to stimulus salience, rather than “top-down” control mechanisms, related to cognitive control. In addition, subjects with high anxiety traits showed reduced prefrontal control of attention [24]. The involvement of the prefrontal cortex (PFC) in the generation and regulation of emotions is well known [25]. While previous research has studied aspects related to the regulation of emotions, fewer studies have investigated the role of the PFC in the processes that generate emotions.

Anxiety has been associated with poor recruitment of the dorsolateral and ventral PFC when the attentional demand is low [24, 26]. In addition, the strength of phasic fear responses is influenced by dysregulation of both the amygdala and the ventrolateral PFC mechanisms. Subjects with high anxiety traits showed reduced connectivity between the ventrolateral PFC and limbic structures [27]. The reduction in the connectivity of subcortical structures impairs the extinction to negative stimuli [28]. Neuroticism was negatively correlated with functional connectivity between both the amygdala and the left lateral orbitofrontal and ventrolateral PFC [29]. Furthermore, Neuroticism modulates amygdala-prefrontal connectivity in response to negative stimuli, and this might be associated with vulnerability to affective disorders [30].

The PFC is a brain region related with various aspects of emotional processes. The PFC has been implicated in self-relevant memory and emotional processes, including pleasure processing during aesthetic experiences [31]. Functional near-infrared spectroscopy (fNIRS) demonstrated the capability of discriminating between affective states on the valence and arousal dimensions [32]. fNIRS uses near-infrared light with spectroscopy principles. Hemoglobin, the oxygen carrier in red blood cells, presents a

differential absorption in the near-infrared wavelengths based on whether it is bonded to the oxygen and allows detection of the changes in concentration of oxygenated and deoxygenated hemoglobin molecules [33]. Several recent studies using fNIRS have found associations between spontaneous human facial affective expressions and relevant brain activity [34]. Rodrigo, Ayaz and Ruocco [35] have examined the neural correlates of incidental facial emotion encoding, with regard to neutral and fearful faces, within the PFC. Results revealed lower levels of activation within the left medial and lateral PFC when viewing fearful faces, compared to neutral faces. In another study, subjects high in Neuroticism and low in Sensation Seeking perceived aversive stimuli as being more aversive than subjects low in Neuroticism and high in Sensation Seeking [36]. Subjects with higher scores in SP showed a tendency of higher startle responses to unpleasant pictures, while subjects higher in SR showed a significant higher startle reflex response in pleasant pictures than lower scorers [37]. In this line, we analyzed PFC activity during the passive viewing of positive and negative emotional pictures using fNIRS recording.

The aim of this research was to study the PFC response to emotional stimuli in one group with high Neuroticism (and low Sensation Seeking) scores and another group with high Sensation Seeking (and low Neuroticism) scores. The passive observation of pictures should allow us to capture individual differences in attention capabilities, such as alerting and orienting, involved in the process of generating emotions. We suggest that subjects in high Neuroticism group might present an activation of automatic processes and/or inhibition of “top-down” mechanisms, producing lower prefrontal activation in response to unpleasant stimuli than in response to pleasant stimuli. This effect is not expected in subjects in high Sensation Seeking group. However, subjects in Sensation Seeking group, characterized by high impulsiveness and low anxiety, might inactivate automatic and/or activate “top-down” processes. This might trigger higher prefrontal activity when viewing pleasant pictures.

2. METHOD

2.1. Participants

Participants were 24 undergraduate female students (mean age: 20; *SD*: 1.74 years). All participants reported no history of neurological or psychopathological disorders or substance abuse. None of the

participants were taking psychotropic medication. Participants were advised to refrain from smoking and/or taking alcoholic or stimulant drinks for at least 12 hours prior to the experiment. Participation was voluntary and financially rewarded with €15. The study was approved by the University's Ethics Committee: All participants were given a detailed explanation of the procedure. Informed consent was obtained from all individual participants included in the study.

2.2. Procedure.

An email was sent to female non-graduate students from the university asking for volunteers to participate in a personality study. Those who accepted the invitation responded to an online version of the Zuckerman-Kuhlman-Aluja Personality Questionnaire (ZKA-PQ). Twenty-five women of the 163 who participated were selected for their extreme scores on the Neuroticism and Sensation Seeking factors. Subjects were distributed in two groups according to means and standard deviation obtained in the entire group in Neuroticism (Mean: 98.08; *SD*: 20.98) and Sensation Seeking (Mean: 95.90; *SD*: 17.52), and using the mean + 1 *SD* in one psychometric scale and lower than the mean in the other scale. Therefore, participants in the high-Neuroticism group have low scores in Sensation Seeking (called Neuroticism group; *N*=11; Mean age: 19.75; *SD*: 1.54), and participants in the high Sensation Seeking group have low scores in Neuroticism (called Sensation Seeking group; (*N*=13; Mean age: 20.25; *SD*: 2.09) (Figure 1).

No significant differences appeared between groups for age in the non-parametric Mann–Whitney *U* test (*U*=58.0; $p = 0.65$). Selected participants were contacted to confirm their participation in the experimental procedure. On arriving at the laboratory, all participants were interviewed by an expert clinical psychologists. No history of emotional disorders was detected in any of them. Before the laboratory task, the participants were informed about the research procedure.

The experiment task consisted of a passive viewing of 10 pleasant and 10 unpleasant pictures that had been selected from the International Affective Picture System (IAPS) [38] based on affective valence using the Spanish validation norms [39]. The activity of the frontal lobe was recorded by means of fNIRS technique. Pictures[1] were pseudo randomly distributed and presented in the same sequence and with the

[1] Pleasant: 8080, 8180, 8370, 5629, 5621, 8161, 8210, 8200, 8030, 8170; Unpleasant: 6550, 3170, 3530, 3150, 3100, 6313, 3080, 6212, 3000, and 6260.

same inter-trial time (18s) for all participants. Each picture was visualized on a 32-inch monitor for 9s. The recording sessions took place in an acoustically and electromagnetically isolated room (Faraday cage) with a compartment for the experimental subject and another for the researcher.

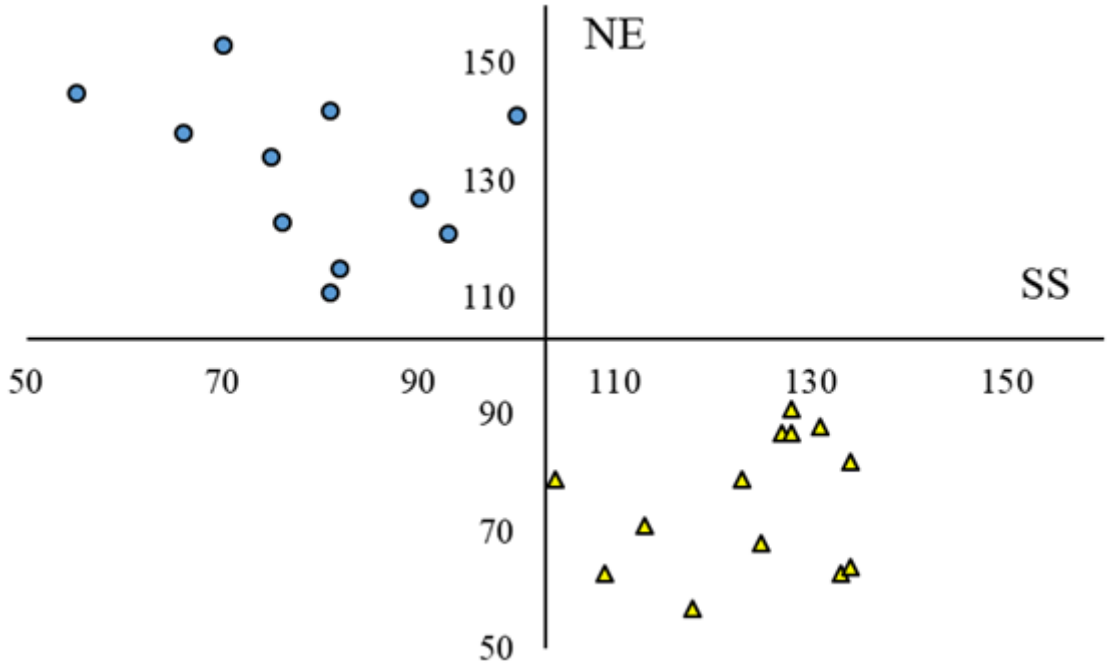

Figure 1. Localitation of each participant for Neuroticism (NE) and Sensation Seeking (SS) bi-dimensional axis. Neuroticism group ● and Sensation Seeking group subjects △. (Color online only).

2.2. Measures.

2.2.1. The Zuckerman-Kuhlman-Aluja Personality Questionnaire (ZKA-PQ).

The personality dimensions were assessed with the Zuckerman-Kuhlman-Aluja Personality Questionnaire [40]. This instrument has 200 items with a 4-point Likert-type response format distributed in 5 factors (Neuroticism, Activity, Aggressiveness, Extraversion and Sensation Seeking). Each factor has 4 facets of 10 items. We used only the Neuroticism and Sensation Seeking factors for this study. Neuroticism includes anxiety, depression, dependency, and low self-esteem facets. Sensation Seeking scales include thrill and adventure seeking, experience seeking, disinhibition, and boredom susceptibility/impulsivity facets.

Both dimensions are orthogonal. Internal consistency for Neuroticism and Sensation Seeking was 0.92/0.85 and 0.93/0.88 for the Spanish and the American original validation ZKA-PQ studies [40].

2.2.2. fNIRS recording.

fNIRS is a noninvasive, safe, and portable imaging method for detecting blood flow activity in the human PFC. We used fNIR 1100 apparatus and COBI data collection suite (Biopac System, Inc.) described in detail elsewhere [41]. The hemodynamic activity (Oxygenated hemoglobin: HbO_2; Reduced hemoglobin: HbR) of the PFC during the experimental session was recorded. We calculated hemoglobin changes according to a baseline taken before the stimulus onset. Total hemoglobin (HbT) and oxygenation changes (Oxy) were obtained from HbO_2 and HbR. The system consists of three elements: a) a flexible headpiece, b) a control box for hardware management, and c) computer software that runs the data acquisition. The headpiece holds 4 light sources and 10 photodetectors. The headband was placed over the eyebrows to register the prefrontal supraorbital regions, aligned with electrode positions F7, FP1, FP2 and F8, based on the International 10–20 EEG System and including Brodmann areas 9, 10, 45 and 46 [35].

The combination of sources and detectors on the headpiece allows us to obtain 16 active optodes (pairs of light source-detectors). Measures of emerging light intensity, at 730 and 850 nm wavelengths, were obtained for each optode. Before the picture presentation, the fNIRS device was calibrated through LED brightness and detector sensitivity to obtain all raw signals between 400 and 4000 mV, while the subject was comfortably seated in the experimental room. Light intensity and signal amplification were also calibrated.

A time window was selected from 0 to 7 s after the stimulus onset. Raw data was low-pass filtered with a finite impulse response (FIR), linear phase filter with order 20 and a cut-off frequency of 0.1 Hz in order to attenuate the high frequency noise, and respiration and cardiac cycle effects [42]. After the application of the FIR filter, the Sliding-window Motion Artifact Rejection (SMAR) algorithm was applied. SMAR detects spikes in the data that resemble subject motion artifacts and channels with readings saturated by external light. Problematic channels were rejected after visual inspection. Intensity measurements at both wavelengths were then converted to relative changes in hemodynamic responses in terms of HbO_2 and HbR

from a starting baseline using the modified Beer–Lambert law. The COBI Studio software [43] was used for data acquisition and visualization.

2.3. Statistical data analysis.

Measures recorded from the optodes were grouped into four separate quadrants: lateral left (optodes 1, 2, 3 and 4), central left (optodes 5, 6, 7 and 8), central right (optodes 9, 10, 11 and 12) and lateral right (optodes 13, 14, 15 and 16). Each area was obtained from the mean of the 4 corresponding channels. A separate analysis was performed for each group: Neuroticism and Sensation Seeking (high N and low SS, and high SS and low N respectively). Raw data on the oxygenation variation during picture presentation showed high between-subjects variability. In order to reduce this variability, hemodynamic variables were transformed to within-subjects T-scores. Nonparametric statistics were used because of the sample size. Wilcoxon Signed-ranks tests (two-tailed) were performed in order to assess hemodynamic changes in the PFC when subjects viewed pleasant or unpleasant pictures. If Z significance level is equal to or less than 0.05, it can be concluded that, the difference between two scores is statistically significant.

3. RESULTS

Separate analysis of hemodynamic variables for the two personality groups presented differences for the high Neuroticism group but not for the high Sensation Seeking group. Table 1 displays a separate analysis of hemodynamic variables for the two personality groups. We found differences for the high Neuroticism group but not for the high Sensation Seeking group. Wilcoxon Signed-ranks test indicated that participants from the Neuroticism group show higher oxygenation changes in the left lateral PFC in response to unpleasant pictures (52.28) than to pleasant pictures (47.72), $Z = 2.49$, $p = 0.01$. Similar results were found for HbO_2 ($Z = 2.49$, $p = 0.01$) and HbT ($Z = 2.40$, $p = 0.02$), but not for HbR ($Z = 1.07$, $p = 0.29$). Analogous results, but less statistically significant, can be observed for the right lateral PFC. Participants with high scores on Neuroticism exhibited higher oxygenation changes when viewing unpleasant pictures (52.15) than when viewing pleasant pictures (47.85), $Z = 2.19$, $p = 0.03$. Similarly to what happened in the left hemisphere, this effect also emerged for HbO_2 ($Z = 2.29$, $p = 0.02$) and HbT ($Z = 2.29$, $p = 0.02$), but

not for HbR (Z = 0.46, p = 0.65). Post-hoc analyses of the individual optodes, which indicated significant differences for Oxygenation changes mainly in the inferior optodes of the lateral left PFC, optode 2 (p = 0.01) and optode 4 (p = 0.03). In the superior optodes, a tendency towards statistical significance appeared, optode 1 (p = 0.05) and optode 3 (p = 0.07). For the right lateral side, statistical significance was only observed for optode 16 (p = 0.04) and a tendency toward the significance for the optode 15 (p = 0.09).

Table 1. Wilcoxon Signed-rank tests differences in hemodynamic variables during viewing pleasant and unpleasant pictures (standardized data) for each prefrontal quadrant in Neuroticism and Sensation Seeking group.

Neuroticism group (N = 11)												
	HbO_2			HbR			HbT			Oxy		
	Pl	Un	*Z*	Pl	Un	*Z*	Pl	Un	*Z*	Pl	Un	*Z*
Lateral Left	52.32	47.68	**2.49****	49.89	50.11	1.07	52.22	47.77	**2.40***	52.28	47.72	**2.49****
Central Left	50.83	49.14	1.40	49.97	50.02	0.14	50.96	49.02	1.26	50.19	49.80	1.12
Central Right	50.76	49.24	1.48	49.88	50.12	0.06	51.02	48.98	1.24	49.93	50.07	0.77
Lateral Right	52.35	47.74	**2.29***	49.92	50.08	0.46	51.91	48.09	**2.29***	52.15	47.85	**2.19***
Sensation Seeking group (N = 13)												
	HbO_2			HbR			HbT			Oxy		
	Pl	Un	*Z*	Pl	Un	*Z*	Pl	Un	*Z*	Pl	Un	*Z*
Lateral Left	51.06	48.94	1.57	49.56	50.44	1.50	50.80	49.20	1.36	50.76	49.24	1.71
Central Left	50.71	49.29	0.06	50.57	49.43	0.77	50.31	49.69	0.65	49.77	50.23	0.89
Central Right	49.82	50.17	1.10	49.80	50.20	0.55	49.64	50.38	0.94	49.66	50.35	1.10
Lateral Right	50.70	49.30	0.87	49.98	50.02	0.87	50.92	49.08	0.45	50.34	49.66	0.52

Note: HbO_2: Oxygenated hemoglobin; HbR: Reduced hemoglobin; HbT: Total hemoglobin; Oxy: Oxygenation Changes. Pl: Pleasant; Un: Unpleasant. Significant Z in boldface. *p < 0.05; ** p < 0.01.

Figure 2 illustrates with two graphs the oxygenation changes for pleasant and unpleasant pictures for the Neuroticism and Sensation Seeking groups. Figure 3 represents the hemodynamic differences in subjects from the Neuroticism group for each optode while viewing pleasant and unpleasant pictures. Hemodynamic responses registered for pleasant and unpleasant pictures did not show significant differences (all p-values > 0.17) between the Neuroticism group and Sensation Seeking group in any quadrant analyzed (U test). However, Neuroticism group presented lower HbO_2 levels than Sensation Seeking group, although the differences were not statistically significant.

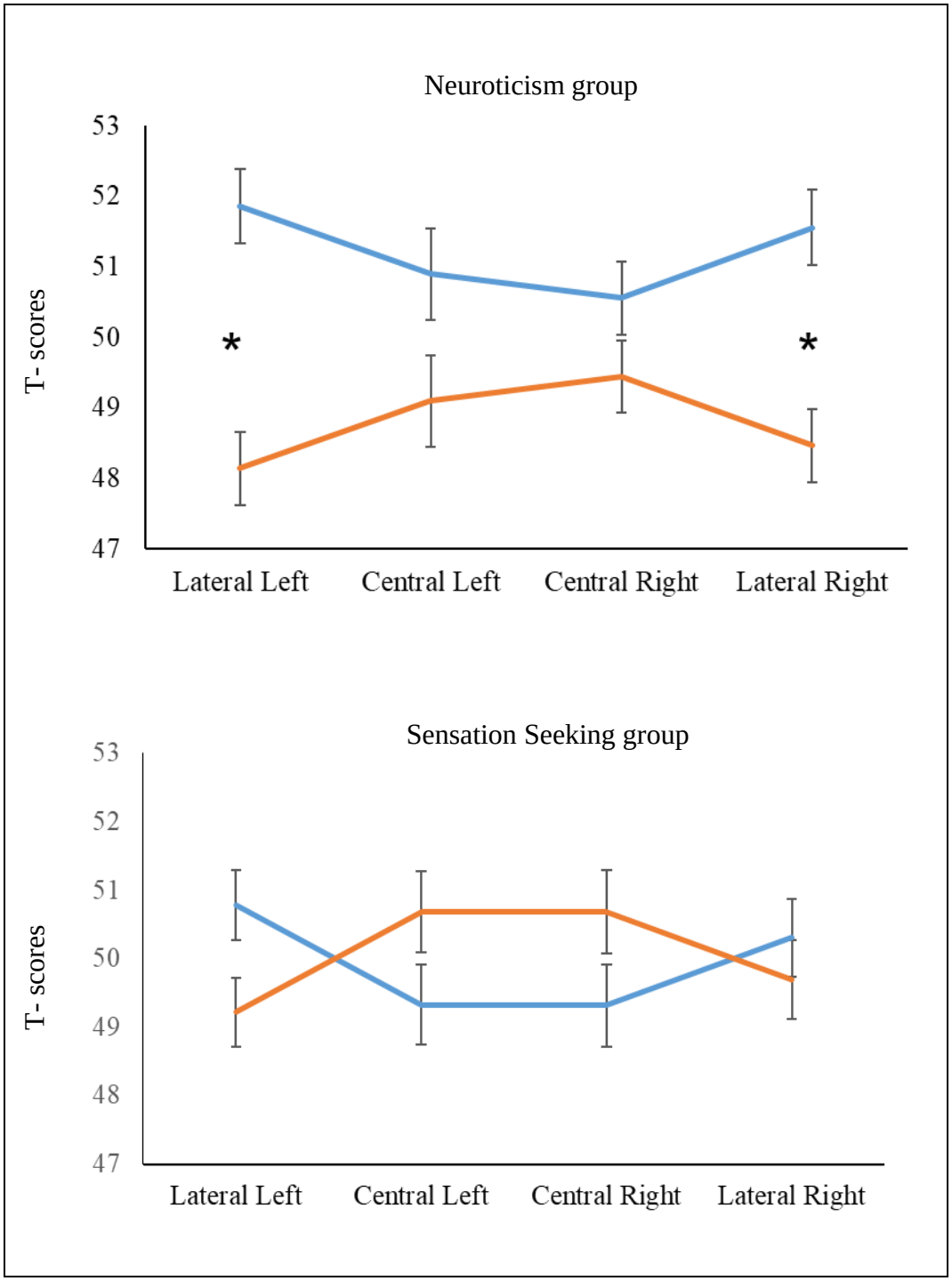

Figure 2. Oxygenation changes for pleasant and unpleasant pictures for each quadrant for Neuroticism and Sensation Seeking groups (*$p < 0.05$) (Blue = Pleasant pictures; Orange = Unpleasant pictures). (Color online only).

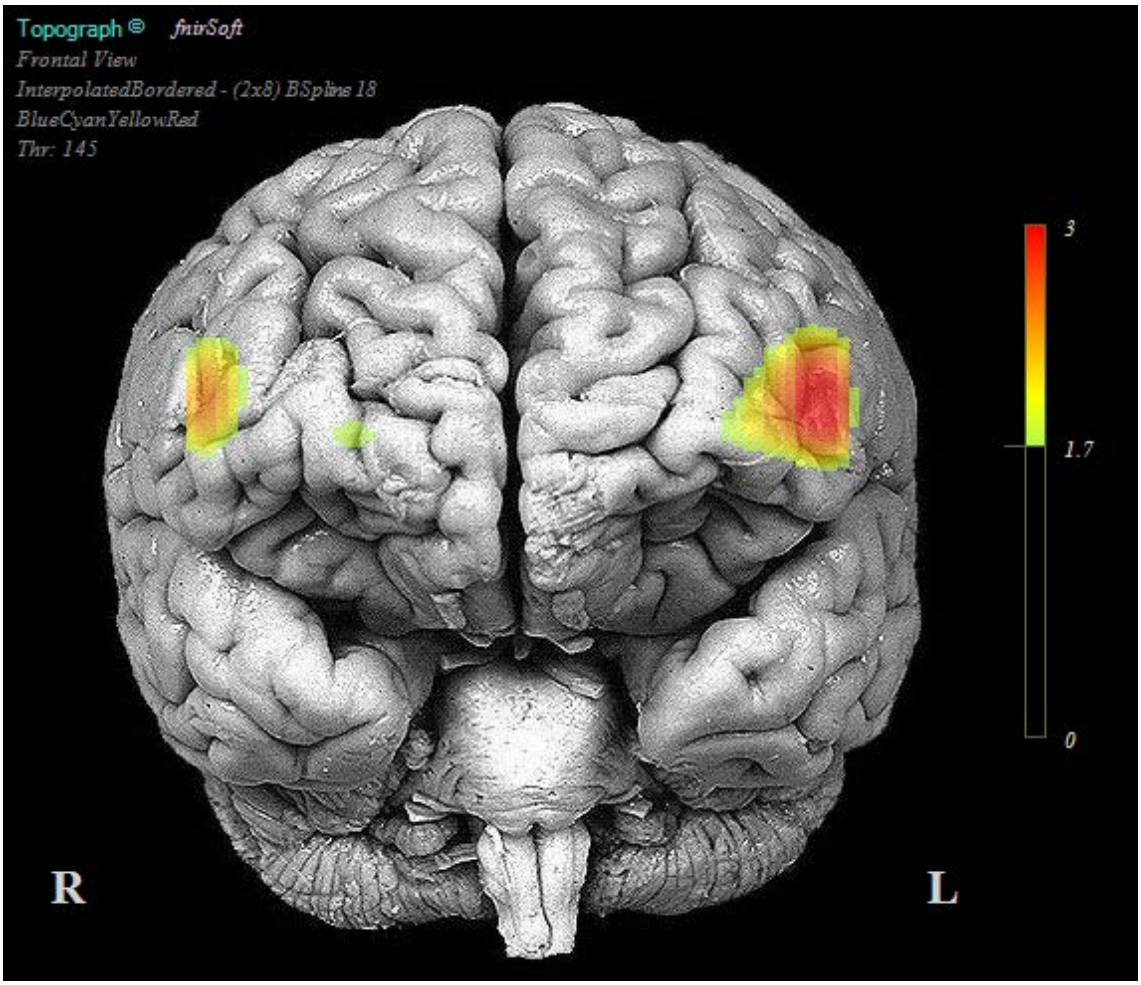

Figure 3. Topographic representation over Brain Surface Image from Digital Anatomic Project (University of Washington) showing *Z* values in oxygenation levels when comparing the PFC activity during viewing pleasant and unpleasant pictures in high scorers in Neuroticism scale. The red color denotes higher Oxy differences indicating greater PFC activity for pleasant compared to unpleasant pictures (Color online only).

4. DISCUSSION

This study was designed to assess the prefrontal activity associated with the visualization of emotional pictures. Subjects high in Neuroticism showed differences in lateral, mainly left, PFC oxygenation regarding the emotional valence of pictures. This effect did not appear for subjects with high scores in Sensation Seeking.

The lateral PFC may be involved in attending to and evaluating the emotional responses generated by other cortical and subcortical structures (Dixon, Thiruchselvam, Todd and Christoff [25]. Lower prefrontal activity might indicate a maladaptive emotion regulation and over-

reactivity of the amygdala in emotional response [28] in the presence of unpleasant stimuli [19, 30]. In fact, increased amygdala activity appears to detect the motivational saliency of fear, disgust or sadness experiences [44], influencing hippocampal dynamics through an amygdala-hippocampal network [45]. A fronto-hippocampal inhibitory pathway has been described with the ability to suppress unwanted thoughts [46]. The link between the amygdala and prefrontal areas would be bidirectional, although in the case of the lateral prefrontal areas it would be marginal and predominantly within most ventral areas [47-49].

One of the mechanisms that may be involved in the lack of prefrontal activation to negative stimuli, and therefore the absence of "top-down" inhibition of the PFC to the amygdala, would be related to the serotoninergic functioning. De Raedt and Koster [50] proposed that a decreased activity in the prefrontal areas, mediated by the serotonin metabolism, which is controlled by the Hypothalamic-Pituitary-Adrenal axis, is associated with an impaired attenuation of the subcortical regions, resulting in a prolonged activation of the amygdala in response to stressors in the environment. In fact, Battaglia, Zanoni, Taddei, Giorda, Bertoletti, Lampis, Scaini, Cappa and Tettamanti [51] found that the short form of serotonin transporter, related to anxiety and depression traits, was associated with higher left amygdala response to anger.

Although in our study significant differences appeared in both dorsolateral and ventrolateral areas, these were more relevant in the latter. The dorsolateral PFC has been associated with cognitive control processes, whereas the ventrolateral PFC interferes by reducing subjective negative affect [52, 53]. The ventral system would include structures such as the amygdala, insula, ventral striatum, ventral regions of the anterior cingulate gyrus and the PFC. It has been linked with the identification of emotional meaning and production of affective states [54]. This system would be relevant for automatic regulation, whereas the dorsal system would be more implicated in executive functions. The dorsal frontoparietal network and the dorsolateral PFC would be involved in “top-down” mechanisms, whereas the ventral frontoparietal network would mediate “bottom-up” processes [55].

A second aspect to highlight from our results is the higher differences of the left side compared to the right lateral PFC in high Neuroticism subjects. Different neuroimaging studies have obtained results supporting the hypothesis of brain asymmetry in response to the stimulus valence [56-62]. However, other authors have discarded the existence of this asymmetry suggesting the existence of different patterns in cerebral blood flow changes that could be used for classifying emotions [63].

Lapate, Samaha, Rokers, Hamzah, Postle and Davidson [64] have shown that the inhibition of the left lateral PFC using transcranial magnetic stimulation causes an emotional evaluation bias according to the emotional pictures previously shown. In our study, we can see how this structure responds differently depending on the emotional load of the stimuli in subjects with high levels of Neuroticism but not in those with high levels of Sensation Seeking. These oxygenation differences in the left lateral PFC might also be related to timing differences. Kohno, Noriuchi, Iguchi, Kikuchi and Hoshi [65] indicated that the timing of emotional discrimination during unpleasant picture stimuli was 2.1s in the left ventrolateral PFC; and 3.6s in the right amygdala preceding the left amygdala and 8.1s in the right ventrolateral PFC. The earlier timing for left ventrolateral PFC could be related to the semantic processing of unpleasant pictures, whereas the right ventrolateral PFC could be related to response inhibition [65]. These differences in timing might be the cause of the differences between left and right lateral PFC observed in our study, because we analyzed the response to stimuli for 7s. Nevertheless, the left ventral and dorsal lateral PFC involved in top-down emotion generation [19] and reappraisal recruits broad areas of the PFC, including the dorsolateral and ventrolateral areas, were often more heavily left sided [48]. A left-lateralized cognitive and intentional control of mood has been hypothesized [61, 66], and maladaptive functioning might be responsible for mood disorders vulnerability [28, 67, 68].

This study has both limitations and strengths. First, this study has been conducted only with women. The greater emotionability of women compared to men can be a distorting factor of the results obtained. However, it must be kept in mind that the study has been carried out with subjects selected for their extreme values in the dimensions studied, and who therefore did not

reflect the totality of the population. We selected only female participants because of their higher responsiveness to emotional stimuli [69]. These results should also be ratified with a group of men selected using the same criteria. The possible connections between the low lateral prefrontal activity and the over-activation of the amygdala in response to unpleasant pictures in subjects with high Neuroticism is only an inference based in the revised literature, since the amygdala has not been directly analyzed in the present study.

Additionally, it would be interesting in future studies to replicate these findings in a clinical sample. Moreover, the limited sample size could have affected the power to detect significant positive findings. The selection of groups on the basis of high values in one dimension and low in the other is limiting, given the difficulty of finding subjects that fulfill these criteria. In any case, the consistency of the results and the observation of the confidence intervals allow us to draw conclusions. However, there are some strengths worth noting. From a dimensional conception, the use of participants with high Neuroticism scores (and low Sensation Seeking scores) or high Sensation Seeking scores (and low Neuroticism scores) allowed us to analyze the prefrontal function in response to stimuli without the presence of masking effects of emotional disorders symptomatology. In addition, our subjects were not taking psychotropic medication that could have interfered.

In summary, our results indicate a differential mechanism of emotion regulation in high Neuroticism subjects according to the stimulus valence. In these subjects, unpleasant stimuli were associated with lower oxygenation levels than pleasant stimuli in the lateral PFC, mainly on the left side. These differences might indicate an attentional bias for negative stimuli that implies an under-activation of the lateral PFC and an over-activation of subcortical structures such as the amygdala. In contrast, Sensation Seeking subjects did not present differences in lateral prefrontal activation after viewing pleasant or unpleasant pictures, which makes it possible to adjust subcortical structures and regulate emotional response. Thus, these data suggest that the Neuroticism/Negative emotionality personality trait would be related to vulnerability to emotional disorders, and contribute to their comorbidity, while the differences in Sensation

Seeking/Disinhibition would be responsible for the phenotypic differences between internalizing and externalizing disorders.

Compliance with ethical standards:

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Conflict of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

Ethical approval: All procedures performed were in accordance with the ethical standards of the institutional research committee “Comité Ètic de l’Hospital Arnau de Vilanova” of the University of Lleida (Spain), and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

Figure Captions

Figure 1. Localitation of each participant for Neuroticism (NE) and Sensation Seeking (SS) bi-dimensional axis. Neuroticism group ● and Sensation Seeking group ▲ subjects . (Color online only).

Figure 2. Oxygenation changes for pleasant and unpleasant pictures for each quadrant for Neuroticism and Sensation Seeking groups (*$p < 0.05$) (Blue = Pleasant pictures; Orange = Unpleasant pictures) (Color online only).

Figure 3. Topographic representation over Brain Surface Image from Digital Anatomic Project (University of Washington) showing *Z* values in oxygenation levels when comparing the PFC activity during viewing pleasant and unpleasant pictures in high scorers in Neuroticism scale. The red color denotes higher Oxy differences indicating greater PFC activity for pleasant compared to unpleasant pictures (Color online only).

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