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Emotional processing prospectively modulates the impact of anxiety on COVID-19 pandemic-related post-traumatic stress symptoms: an ERP study

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ABSTRACT

Background: Considering that the elevated distress caused by the COVID-19 pandemic, in some cases, led to post-traumatic stress symptoms (PTSS), it has been proposed as a specific traumatic event. The present longitudinal study investigated pre-pandemic motivated attention to emotional stimuli, as indexed by Late Positive Potential (LPP) amplitude, in relation with the potential differential role of anxiety and depressive symptoms in predicting PTSS severity related to the COVID-19 pandemic.

Methods: A total of 79 university students initially completed self-report measures of depression and anxiety along with a passive viewing task of emotional (pleasant, unpleasant) and neutral pictures while electroencephalographic activity was recorded. In December 2020, 57 participants completed a questionnaire assessing PTSS.

Results: Significant interactions between anxiety and LPP emerged in predicting pandemic-related PTSS, where greater anxiety symptoms predicted PTSS only in individuals with greater LPP to unpleasant or with reduced LPP to pleasant stimuli.

Limitations: The prevalence of the female sex, the relatively young age of the participants, as well as the fact that they were all enrolled in a University course might not allow the generalization of the findings.

Conclusions: Taken together, the present longitudinal study provided novel evidence on EEG predictors of pandemic-related PTSS that might be useful for the prevention and treatment of PTSS. Indeed, assessing anxiety symptoms and pre-trauma LPP to emotional stimuli might be a useful target for identifying individuals that are more vulnerable to the development of PTSS during times of crisis.

1. Introduction

In late December 2019 a pneumonia outbreak caused by the 2019 novel coronavirus (SARS-CoV-2, and then referred to as COVID-19) developed and, due to its highly infectious nature, by March 2020 it was defined as a pandemic by the World Health Organization (WHO, 2020). The lack of preparation of the global community and health systems, the unpredictability linked to the growth of COVID-19 cases and victims, together with the imposed social distancing restrictions and the high mass-media coverage, lead to detrimental mental health consequences. In particular, several studies documented elevated depressive, anxiety, and post-traumatic stress symptoms (PTSS) in the general population (e.g., Coloma-Carmona and Carballo, 2021; Ebrahimi et al., 2021; Forte et al., 2020; Horesh and Brown, 2020; Lahv, 2020; Rossi et al., 2020; Tang et al., 2020; Wang et al., 2020; Vindegaard and Eriksen Benros, 2020; Zhu et al., 2021). Considering that the elevated distress caused by the COVID-19 pandemic, in some cases, led to PTSS, it has been proposed as a specific mass traumatic event (Bridgland et al., 2021; Horesh and Brown, 2020).

Exposure to traumatic life-threatening events (e.g., war, natural disasters, severe accidents, sexual assaults) is associated with the onset of post-traumatic stress disorder (PTSD), a highly disabling psychiatric disorder mainly characterized by a hyperreactivity to and a failure to recover from unpleasant events (Santiago et al., 2013). According to the Diagnostic and Statistical Manual of Mental Disorders (DSM–5; American Psychiatric Association, 2013), PTSD includes avoidance of trauma-related stimuli, intrusive thoughts, and hyperarousal. Individuals with PTSD were consistently shown to experience

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hyperreactivity to negative stimuli (Hayes et al., 2012; Lobo et al., 2011; Shin et al., 2005) and an excessive aversion to risks (Admon et al., 2013). These findings align with an alteration of the Negative Valence System domain of the Research Domain Criteria (RDoC), a clinical research model developed to better characterize the affective, cognitive, and physiological factors underlying psychopathology (Insel et al., 2010; Kozak and Cuthbert, 2016). In addition, several studies suggest that PTSD might be characterized by an alteration of the Positive Valence System of the RDoC matrix, indicated by anhedonia, feelings of detachment from others, and a reduced reward-seeking behavior (Elman et al., 2005; Nawiij et al., 2015; Kalebasi et al., 2015; Sailer et al., 2008; Seidemann et al., 2021).

Meta-analytic evidence reported elevated individual differences in how individuals respond to trauma, where only about 15–30% of those exposed to traumatic stressors develop PTSD (Santiago et al., 2019). An initial stress response following a traumatic event is highly common but temporary for the majority of the population, where relatively few individuals develop persistent symptoms (Bonanno et al., 2011). Several predictors of PTSD onset have been identified, including a family history of psychopathology, poor social support, maladaptive emotion regulation strategies, and prior depressive and anxiety symptoms (Brewin et al., 2000; Breslau et al., 1991; Fauserbach et al., 1997; Larson et al., 2008; North et al., 1994; Ozer et al., 2003; Powers et al., 2014; Wild et al., 2016; Shalev et al., 1998). Particularly, depressive and anxiety symptoms, repeatedly reported in individuals suffering from PTSD (Armour et al., 2014; Brady et al., 2000), were suggested to prospectively increase the risk to develop PTSD following a traumatic event (Blanchard et al., 1994; Brady et al., 2000; Edmondson et al., 2014; Gulliver et al., 2021). Although the underlying mechanism for this vulnerability is still unclear, it can be hypothesized that differential patterns of attentional processing of emotional (pleasant and unpleasant) content may represent a measure modulating the link between pre-trauma anxiety and depressive symptoms and PTSS onset (Dickey et al., 2021; Lieberman et al., 2017).

A possible explanation of this close link might lie in the preferential processing of unpleasant stimuli as a core feature of anxiety and depression (Bar-Haim et al., 2007; Dillon et al., 2014; Kujawa et al., 2015; White et al., 2016; Clark and Beck, 2010; LeMoulit and Gotlib, 2019). Indeed, previous studies reported that individuals with depressive symptoms were more reactive to laboratory stressors, as indicated by elevated heart rate, blood pressure responses, and higher cortisol levels during the post-stress recovery period (Betensky and Contrada, 2010; Burke et al., 2005; Kibler and Ma, 2004). However, while these findings suggest a heightened physiological reactivity to negative stressors in depression (Edmondson et al., 2014), numerous recent studies corroborate with the view that depression is predominantly associated with a blunted reactivity towards positively-valenced content (e.g., Sloan et al., 2001; Messerotti Benvenuti et al., 2015; Messerotti Benvenuti, Buodo, et al., 2017; Messerotti Benvenuti, Mennella, et al., 2017, Messerotti Benvenuti et al., 2019; Nelson et al., 2016; Winer and Salem, 2016). In the same line, the heightened processing of unpleasant stimuli in individuals with pre-trauma anxiety was suggested to intensify the negative features of traumatic events (e.g., Sloan et al., 2001; Messerotti Benvenuti et al., 2015; Messerotti Benvenuti, Buodo, et al., 2017; Messerotti Benvenuti, Mennella, et al., 2017, Messerotti Benvenuti et al., 2019; Nelson et al., 2016; Winer and Salem, 2016). In the same line, the heightened processing of unpleasant stimuli in individuals with pre-trauma anxiety was suggested to intensify the negative features of traumatic events (e.g., Sloan et al., 2001; Messerotti Benvenuti et al., 2015; Messerotti Benvenuti, Buodo, et al., 2017; Messerotti Benvenuti, Mennella, et al., 2017, Messerotti Benvenuti et al., 2019; Nelson et al., 2016; Winer and Salem, 2016).

A psychophysiological measure of the processing of emotional stimuli is obtained through the analysis of event-related potentials (ERPs). Particularly, the Late Positive Potential (LPP) is a sustained positive deflection beginning approximately 300 ms post-stimulus and reflects the elaborative processing of motivationally salient content, namely motivated attention (Cuthbert et al., 2000; Schupp et al., 2000). Indeed, an increased LPP in response to emotional stimuli (pleasant and unpleasant) relative to neutral has been consistently reported (Hajcak et al., 2010). Interestingly, LPP was found to correlate with the activity of an extended network of cortical and subcortical regions involved in emotional processing (Bunford et al., 2018; Sabatinelli et al., 2013). Given the sensitivity of LPP to discriminate emotional relative to neutral cues, there has been a growing interest in examining whether it can be considered a correlate of differential attention patterns to pleasant and/or unpleasant content in depressive and anxiety symptoms. Regarding depressive symptoms, there is little evidence supporting an increased LPP to unpleasant stimuli in depressive symptoms (Asnerbach et al., 2015; Speed et al., 2016), with some other studies contrasting it (e.g., Foti et al., 2010). Instead, a reduced LPP to pleasant stimuli was robustly reported in individuals with depression (Grunewald et al., 2019; Klawohn et al., 2021; Weinberg et al., 2016; for a review see Hajcak Proudfit et al., 2015), in children with depressive symptoms (Whalen et al., 2020) or at risk for depression (Levinson et al., 2019; Nelson et al., 2015). Instead, previous studies linked anxiety symptoms with an increased LPP in response to unpleasant and threatening stimuli (Kujawa et al., 2015; MacNamara et al., 2019). Given that PTSD was considered an anxiety disorder (APA, 2000), similar LPP patterns to the ones found in anxiety were documented for individuals with PTSD. Particularly, enhanced motivated attention to unpleasant stimuli, indexed by an increased LPP amplitude to negatively-valenced and trauma-specific cues, was reported in individuals with PTSD relative to non-PTSD trauma-exposed individuals (Macatee et al., 2021; Miller et al., 2020; Wessa et al., 2006; Stanford et al., 2001; Karl et al., 2006; Klein et al., 2019) and in individuals with subthreshold PTSD symptoms (Lobo et al., 2014).

To date, only a few studies have prospectively investigated the LPP amplitude to affective stimuli as a predictive measure of future onset of PTSS. For example, larger LPP amplitude to unpleasant images prior to the exposure to a natural disaster predicted the severity of stress-related oppositional and aggressive behavior, while reduced LPP to pleasant images predicted the severity of anxiety and depressive symptoms in children (Kujawa et al., 2016). Moreover, a recent longitudinal study that investigated the prospective predictors of the response to the COVID-19 pandemic revealed that reduced LPP amplitude to pleasant stimuli predicted increases in anxiety and depressive symptoms, while enhanced LPP amplitude to unpleasant stimuli predicted increases in traumatic intrusions (Dickey et al., 2021). Further, smaller LPP amplitude to unpleasant stimuli in individuals with PTSD predicted a steeper decline in symptoms over a one-year time frame (Fitzgerarld et al., 2018). These findings suggest that LPP amplitude to emotional stimuli may expose individuals to different levels of stress responses.

Due to the unpredictable nature of trauma-related stressors, there is a lack of longitudinal studies that examined psychological and neurophysiological correlates that characterize the risk to develop maladaptive stress responses. Yet, the investigation of premorbid features is crucial to better identify individuals that might suffer from severer consequences following trauma exposure and that might benefit from close monitoring and early intervention strategies. To this end, the present longitudinal study aimed at investigating pre-pandemic motivated attention to emotional stimuli, as indexed by LPP amplitude, in relation with the potential differential role of anxiety and depressive symptoms in predicting PTSS severity related to the COVID-19 pandemic. Particularly, LPP amplitude to emotional (pleasant and unpleasant) and neutral pictures, anxiety, and depressive symptoms were assessed at baseline pre-pandemic (December 2019 – February 2020) in a sample of Italian University students. In December 2020, a one-year
follow-up assessment of pandemic-related PTSS was conducted. In light of the reviewed literature, it was hypothesized that the enhanced risk to develop PTSS, conferred by higher anxiety and depressive symptoms, could be moderated by differential patterns of pre-pandemic motivated attention to emotional stimuli. In particular, due to the consistent involvement of the Negative Valence System in anxiety (e.g., Kujawa et al., 2015; MacNamara et al., 2019), it was hypothesized that the enhanced motivated attention to unpleasant stimuli, indexed by increased LPP amplitude to these stimuli, would moderate the link between pre-trauma anxiety and subsequent PTSS. Instead, due to the consistent involvement of the Positive Valence System in depressive symptoms (e.g., Klawohn et al., 2021; Weinberg et al., 2016), it was hypothesized that reduced motivated attention to pleasant stimuli, indexed by decreased LPP amplitude to these stimuli, would moderate the link between pre-trauma depression and subsequent PTSS.

2. Methods

2.1. Participants

The present study was conducted within an extensive research project that also included an electrocardiogram (ECG) recording (see Dell’Acqua et al., 2020, 2021 for more details on ECG data recording, analysis, and results). A total of 79 (24 males, 55 females, mean (M) age = 20.4, standard deviation (SD) = 2.5) Italian Caucasian University students voluntarily took part in the study. The enrolled sample was medically healthy and free from psychotropic medication, as assessed with an ad-hoc anamnestic interview. Exclusion criteria included a current and past history of cardiovascular, psychiatric, and neurological diseases. All participants had a normal or corrected-to-normal vision, were righthanded and were naive to the purpose of the experiment. Participants were compensated for their participation (13 € for the baseline pre-pandemic assessment and 18 € for the one-year follow-up). Of the original 79 participants, 57 (16 males, 41 females) accepted to take part in the online follow-up approximately 12 months following the initial laboratory assessment, between December 2020 and February 2021. Hence, 72% of the cohort completed both assessments. At the follow-up, the attained mean age was of 21.6 years (SD = 2.8). The present study was conducted with the adequate understanding and written consent of the participants in accordance with the Declaration of Helsinki and was approved by the local Ethics Committee, University of Padua (prot. no. 3612).

2.2. Measures

2.2.1. Psychological measures

Depressive symptoms were assessed using the Beck Depression Inventory-II (BDI-II; Beck et al., 1996; Italian version by Ghisi et al., 2006). The BDI-II is a reliable and valid self-report questionnaire developed to assess the severity of current depressive symptoms in the past two weeks. Specifically, the BDI-II is composed of 21 items, each based on a four-point Likert scale and scores range from 0 to 63, with highest scores indicating greater depressive symptoms (Ghisi et al., 2006).

Anxiety symptoms were assessed using the Beck Anxiety Inventory (BAI; Beck, 1990; Italian version by Sica et al., 2007). The BAI is a self-report questionnaire developed to assess the severity of anxiety in adults by assessing its emotional, cognitive, and physiological correlates. Specifically, the BAI is composed of 21 items, each based on a four-point Likert scale and scores range from 0 to 63, with highest scores indicating greater anxiety symptoms (Sica et al., 2007).

The psychological impact of COVID-19 was assessed using the Impact of Event Scale-Revised (IES-R, Weiss and Marmar, 1997; Weiss, 2007, Italian version by Pietrantonio et al., 2003). The IES-R is a self-report questionnaire developed to assess post-traumatic stress symptomatology in the past week and was already employed in the assessment of COVID-19 pandemic-related PTSS (e.g., Davico et al., 2021; Forte et al., 2020). The IES-R is composed of 22 items, each based on a five-point Likert scale. A total IES-R score equal to or below 23 can be considered normal, a score between 24 and 36 represents mild-to-moderate PTSS and a score above or equal to 37 represents severe PTSS (Creamer et al., 2003; Pietrantonio et al., 2003).

Internal consistency resulted high for the 21 items of the BDI-II (Cronbach’s α = 0.90), the 21 items of the BAI (Cronbach’s α = 0.91) and the 22 items of the IES-R (Cronbach’s α = 0.93). Participants completed the BDI-II and BAI questionnaires at baseline pre-pandemic, while they completed the IES-R at follow-up between December 2020 and February 2021.

2.2.2. Experimental task

EEG was recorded while participants underwent a passive viewing task of affective pictures. The task involved the viewing of 72 digitized color pictures (600 × 800 pixels), divided into three categories: 24 pleasant (e.g., erotic couples, sports), 24 neutral (e.g., neutral faces, household objects), and 24 unpleasant (e.g., attacking humans and animals) selected from the International Affective Picture System (IAPS; Lang et al., 2008)1 on the basis of their standardized valence and arousal ratings. Only highly arousing pleasant and unpleasant pictures were selected since these have been observed to induce elevated psychophysiological changes (e.g., Bradley et al., 2001). Pleasant and unpleasant pictures were matched for normative arousal ratings which were significantly higher than for neutral pictures.

Each picture was preceded by a 3000 ms gray interval with a white fixation cross placed centrally on the screen. Participants were required to look at the central fixation cross and keep their gaze on the center of the screen. Pictures were presented for 6000 ms each in a semi-randomized sequence (i.e., no more than one image in the same emotional condition was shown consecutively). Picture presentation was followed by a variable intertrial interval (ITI) of 6000–8000 ms, during which a white fixation cross (identical to the 3-sec baseline) was presented. Prior to the execution of the passive viewing task, a 3-minute resting-state period and six practice trials including two pleasant, two neutral, and two unpleasant pictures were provided. At the end of the passive viewing task, 36 pictures (12 for each emotional category) were presented again, and ratings of emotional valence and arousal were obtained using a computerized version of the 9-point Valence and Arousal scales of the Self-Assessment Manikin (SAM; Bradley and Lang, 1994).

2.3. Procedure

After signing the informed consent, participants were administered an ad-hoc anamnestic interview and then completed the BDI-II and the BAI self-report measures. Subsequently, they were seated on a comfortable chair in a dimly lit, sound-attenuated room and completed the passive viewing task. The entire procedure lasted approximately 90 min. A one-year follow-up assessment was conducted online between December 2020 and February 2021 and comprised the completion of the IES-R self-report measure.

2.3.1. Electroencephalogram data acquisition and analysis

EEG was recorded using a 32-channel ANT system and a computer running eego™ software (ANT Neuro, Enschede, Netherlands).

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1 The IAPS picture numbers were as follows: 1050, 1114, 1120, 1300, 1302, 1930, 1932, 3500, 4611, 4647, 4651, 4652, 4656, 4660, 4670, 4680, 4683, 4690, 4695, 4810, 6200, 6210, 6230, 6242, 6243, 6244, 6250, 6260, 6312, 6313, 6370, 6510, 6540, 6550, 6560, 7000, 7002, 7004, 7009, 7010, 7020, 7033, 7036, 7041, 7050, 7056, 7059, 7130, 7175, 7224, 7233, 7242, 7491, 7590, 7547, 7560, 7595, 7700, 7950, 8030, 8031, 8034, 8080, 8161, 8180, 8185, 8186, 8200, 8370, 8400, 8490, 9425.
elastic cap with 32 tin electrodes was arranged according to the 10–20 System (Fp1, Fpz, Fp2, F7, F3, Fz, F4, F8, FC5, FC1, FC2, FC6, T7, C3, Cz, C4, T8, CP5, CP1, CP2, CP6, P7, P3, Pz, P4, P8, POz, O1, Oz, O2, and M1 and M2 [mastoids]), referenced online to CPz. To monitor eye movements and blinks, vertical and horizontal electrooculograms (EOGs) were recorded using a bipolar montage. Electrode impedance was kept below 10 kΩ. The EEG and EOG signals were amplified with an eeg amplifier (ANT Neuro, Enschede, Netherlands), bandwidth filtered (0.3–40 Hz), and digitized at 1000 Hz. The EEG signal was downsampled to 500 Hz and re-referenced offline to the linked mastoids as implemented in EEGLAB (Delorme and Makeig, 2004). Further analysis was performed using Brainstorm (Tadel et al., 2011). Data were band-pass filtered from 0.3 to 30 Hz, manually corrected for blink artifacts using independent component analysis (ICA), and segmented for each trial 3000 ms before picture onset to 3000 ms after onset, in order to prevent boundary effects. Each epoch was baseline-corrected by subtracting the mean pre-stimulus voltage between −250 ms and −50 ms. Then, segments containing residual artifacts exceeding ±70 μV (peak-to-peak) were excluded. ERPs were calculated by averaging EEG epochs separately for each participant and emotional condition.

2.4. Statistical analysis

Repeated measures analyses of variance (ANOVA)s with Category (pleasant, neutral, unpleasant) as a within-subjects factor were conducted on self-reported valence and arousal. Significant main effects (p < .05) were followed by Tukey HSD post-hoc tests in order to correct for multiple comparisons.

To extract the LPP complex amplitude, a cluster-based approach has been employed in order to control for overall error rate arising from multiple comparisons across electrodes and time points (Maris and Oostenveld, 2007). The cluster-based statistical test was run over time-points in the −100 to 700 ms interval in frontal, central, parietal, and occipital electrodes (FP1, FPZ, FP2, F7, F3, Fz, F4, F8, FC5, FC1, FC2, FC6, C3, CZ, C4, CP5, CP1, CP2, CP6, P7, P3, Pz, P4, P8, POz, O1, OZ, O2). A p < .05 criterion was employed to threshold the matrices.

To identify the LPP within-subjects differences in amplitudes among emotional categories (pleasant, neutral, unpleasant), cluster-based repeated measures analysis of variance (ANOVA) was employed. As the interest of the present work was to investigate motivated attention to pleasant and unpleasant stimuli, differential scores of LPP amplitude were obtained for each emotional category, such that the amplitude of neutral trials was subtracted from the amplitude of pleasant and unpleasant trials (i.e., pleasant – neutral; unpleasant – neutral). Then, a paired samples t-test was conducted to verify that the differential scores of pleasant and unpleasant trials were not statistically different.

Considering that the male sex was fairly underrepresented, an independent t-test was carried out to examine whether sex influenced the dependent variable of interest (IES-R). Also, as a preliminary analysis, bivariate Pearson’s correlations between the variables of interest (BAI and BDI-II score with LPP to pleasant cues and LPP to unpleasant cues) were conducted to verify that the independent variables included in the regression model were not highly correlated. Then, a multiple linear regression model was conducted to assess the main effect of baseline anxiety (BAI) and depressive symptoms (BDI-II) and differential LPP amplitude for affective images (pleasant and unpleasant) and their interaction in predicting pandemic-related PTSS (IES-R). All variables were centered and scaled: the mean of each variable was subtracted by each value and the resulting value was then divided by the standard deviation of its distribution. Assumptions of multiple regression were tested (Williams et al., 2013). Residual errors from the model were inspected to ensure their normal distribution and thus the reliability of the regression model. Also, the Shapiro-Wilk test was conducted to ensure that data was normally distributed. Additionally, Cook’s distances were computed. The collinearity was tested by calculating the Variance Inflation Factors (VIF) with the vif function of the car package (Fox et al., 2019). A p value of 0.05 was the cut-off for significance. Significant interactions were explored by conducting simple slope analysis at the mean and 1 standard deviation below and above the mean.

3. Results

3.1. Characteristics of the sample

There were no differences in sex (p = .47), age (p = .80), education (p = .50), depressive symptoms (p = .62) or anxiety symptoms (p = .46) between the subsample that participated to the follow-up and the subsample that did not participate. The average BDI-II score at baseline of the whole sample was 10.7 (SD = 9.0) and scores ranged from 0 to 41. At follow-up, the average BDI-II score was 12.0 (SD = 10.5) and scores ranged from 0 to 45. A paired sample t-test showed no changes in depressive symptoms from baseline to the follow-up (t (56) = −1.74, p = .09). Further, the average BAI score of the sample was 11.7 (SD = 9.2) and scores ranged from 0 to 42. At follow-up, the average BAI score was 9.2 (SD = 9.5) and scores ranged from 0 to 38. A paired sample t-test showed changes in BAI scores (t (56) = 2.77, p < .01). Regarding the IES-R, the average score was 26.1 (SD = 17.3) and the scores ranged from 2 to 88. Specifically, the present sample was composed of 32 participants with an IES-R score equal to or below 23 (absence of PTSD), 11 participants with an IES-R score between 24 and 36 (mild-to-moderate PTSS), and 14 participants with an IES-R score above or equal to 37 (severe PTSD). Correlations among study variables are shown in the Supplementary Material.

3.2. Valence and arousal self-report ratings

The ANOVA on valence ratings yielded a significant main effect for Category, F(3,150) = 336, p < .001, η²p = 0.81. Unpleasant pictures were evaluated as significantly more unpleasant than neutral (p < .001) and pleasant (p < .001) pictures. Pleasant stimuli were rated as significantly more pleasant than neutral ones (p < .001). Specifically, the mean (SD) valence ratings for pleasant, neutral, and unpleasant slides were respectively 6.62 (1.10), 5.30 (0.81), 2.90 (0.90). The ANOVA on arousal ratings revealed a significant main effect for Category F(3,150) = 263, p < .001, η²p = 0.80. Specifically, arousal ratings were higher for both pleasant and unpleasant pictures compared to neutral ones (all ps < .001). Unpleasant pictures were rated as more arousing than pleasant stimuli (p < .001). Specifically, the mean (SD) arousal ratings for pleasant, neutral, and unpleasant slides were respectively 5.20 (1.64), 2.50 (1.41), 5.91 (1.64).

3.3. LPP cluster

The cluster-based ANOVA on EEG data showed a significant positive centro-parieto-occipital cluster (electrodes = CP5 CP1 CP2 CP6 P7 P3 PZ P4 P8 POZ) in a time window ranging from 312 ms to 800 ms. The sample revealed a significantly larger LPP complex in response to pleasant and unpleasant stimuli than neutral ones (all ps < 0.01) (Fig. 1). Differential scores of LPP amplitude to unpleasant and pleasant images did not significantly differ (t(78) = −0.60, p = .60).

3.4. The role of pre-pandemic anxiety, depressive symptoms, and LPP to emotional stimuli in predicting pandemic-related PTSS

Bivariate Pearson’s correlations did not reveal any significant association between the independent variables of interest. An independent sample t-test revealed that sex significantly influenced IES-R scores (t (56) = 3.1, p = .01), with females showing higher scores relative to males. Thus, sex was included as a covariate in the regression model. Assumptions of multiple regression were respected and the Shapiro-Wilk test revealed that the data was normally distributed (p = .60).

248
distances was satisfactory (i.e., max value = 0.54, mean = 0.03). The results of the multiple linear regression testing the main and interaction effects of baseline anxiety and depressive symptoms and the differential amplitudes of LPP to pleasant and unpleasant images in the prediction of pandemic-related IES-R scores are shown in Table 1. Sex was a significant predictor, such that females showed higher IES-R scores. A significant interaction between anxiety and LPP to unpleasant images emerged. Simple slopes analysis revealed that the effect of anxiety in predicting IES-R scores was only significant for LPP to unpleasant images 1 SD above the mean (p = .01, Fig. 2 panel a). Moreover, a significant interaction between anxiety and LPP to pleasant images emerged. Simple slopes analysis revealed that the effect of anxiety in predicting IES-R scores was only significant for LPP to pleasant images 1 SD below the mean (p = .01, Fig. 2 panel b). VIF values were all < 5, suggesting adequate levels of multicollinearity among the predictor variables. The main and interaction effects that included depressive symptoms were not significant predictors of IES-R (all ps > .05).

### 4. Discussion

The present longitudinal study sought to investigate pre-pandemic motivated attention to emotional stimuli, as indexed by LPP amplitude, in relation with the potential differential role of anxiety and depressive symptoms in predicting PTSS severity related to the COVID-19 pandemic. Importantly, this was among the first studies to describe the predictive role of affective stimuli processing combined with pre-morbid psychological features on PTSS. The study was based on the evidence suggesting a role of pre-trauma anxiety and depressive symptoms in predicting PTSS following a trauma (e.g., Breslau et al., 1991; Ozer et al., 2003; Powers et al., 2014; Wild et al., 2016). Particularly, it was hypothesized that the enhanced motivated attention to unpleasant stimuli, indexed by increased LPP amplitude, would moderate the link between pre-pandemic anxiety and subsequent PTSS. Instead, it was hypothesized that reduced motivated attention to pleasant stimuli, amplitudes of LPP to pleasant and unpleasant images in the prediction of pandemic-related IES-R scores are shown in Table 1. Sex was a significant predictor, such that females showed higher IES-R scores. A significant interaction between anxiety and LPP to unpleasant images emerged. Simple slopes analysis revealed that the effect of anxiety in predicting IES-R scores was only significant for LPP to unpleasant images 1 SD above the mean (p = .01, Fig. 2 panel a). Moreover, a significant interaction between anxiety and LPP to pleasant images emerged. Simple slopes analysis revealed that the effect of anxiety in predicting IES-R scores was only significant for LPP to pleasant images 1 SD below the mean (p = .01, Fig. 2 panel b). VIF values were all < 5, suggesting adequate levels of multicollinearity among the predictor variables. The main and interaction effects that included depressive symptoms were not significant predictors of IES-R (all ps > .05).

### Table 1

Linear regression model testing the main and interactive effects of pre-trauma anxiety (BAI), depressive symptoms (BDI-II), and LPP to unpleasant and pleasant stimuli in the prediction of pandemic-related PTSS (IES-R scores).

| Predictor                        | Adjusted R² | b (SE) | p     | [95% CI]          |
|----------------------------------|-------------|--------|-------|-------------------|
| Sex (M)                          | .416        |        |       |                   |
| Age                              |             | -0.61 (0.27) | .03   | [−1.15; −0.06]    |
| Differential amplitude LPP to pleasant stimuli |            | 0.03 (0.04) | .50   | [−0.05; 0.11]     |
| Differential amplitude LPP to unpleasant stimuli |            | -0.10 (0.13) | .43   | [−0.36; 0.16]     |
| Baseline BDI-II                  |             | 0.02 (0.14) | .87   | [−0.26; 0.30]     |
| Baseline BAI                     |             | 0.25 (0.20) | .16   | [−0.10; 0.60]     |
| Differential amplitude LPP to pleasant stimuli × BDI-II |             | 0.14 (0.20) | .48   | [−0.26; 0.54]     |
| Differential amplitude LPP to unpleasant stimuli × BDI-II |             | 0.35 (0.02) | .20   | [−0.18; 0.87]     |
| Differential amplitude LPP to unpleasant stimuli × BAI |             | -0.18 (0.21) | .40   | [−0.61; 0.25]     |
| Differential amplitude LPP to pleasant stimuli × BAI |             | -0.62 (0.25) | .02   | [−1.12; −0.12]    |
| Differential amplitude LPP to unpleasant stimuli × BAI |             | 0.34 (0.16) | .04   | [0.01; 0.66]      |

Note. b = unstandardized coefficient; SE = standard error; LPP = late positive potential; BDI-II = Beck Depression Inventory-II; BAI = Beck Anxiety inventory; CI = confidence intervals; M = male. Significant effects are displayed in bold.
indexed by decreased LPP amplitude to these stimuli, would moderate the link between pre-pandemic depression and subsequent PTSS.

As expected, a significant interaction effect between anxiety symptoms and LPP amplitude to unpleasant images emerged, where only high LPP amplitude to these stimuli predicted a positive association between pre-pandemic anxiety and pandemic-related PTSS. This result is in line with previous studies that reported higher PTSS in individuals with pre-trauma anxiety (e.g., Breslau et al., 1991; Larsson et al., 2008; Özer et al., 2003; Powers et al., 2014; Wild et al., 2016). However, previous studies have been unable to disentangle the mechanisms linked to this vulnerability. Instead, the present finding suggests that the link between pre-pandemic anxiety and subsequent PTSS is moderated by a greater tendency to process unpleasant stimuli. Larger LPP amplitude reflects greater attention towards motivationally salient stimuli (Cuthbert et al., 2000; Hajcak et al., 2011), while the employment of emotion regulation strategies aimed at downregulating the unpleasantness of a cue diminishes the magnitude of this component (Hajcak and Nieuwenhuis, 2006; Hajcak et al., 2011; Moser et al., 2006). Hence, a greater LPP amplitude to unpleasant images may denote a higher motivation to allocate attention to unpleasant stimuli and a difficulty in downregulating its affective content (Kujawa et al., 2016). This finding is partly in line with a recent study reporting that a greater LPP amplitude to threatening stimuli at baseline predicted an enhanced association between perceived stress during the COVID-19 pandemic and traumatic intrusions (Dickey et al., 2021). Specifically, under elevated exposure to pandemic-related stressors, individuals with higher LPP amplitude to threatening stimuli were more likely to experience PTSS. The present work extended these previous findings by showing that PTSS are predicted by anxiety symptoms when individuals show greater motivated attention to emotional stimuli. This finding could be due to the insufficient range of variability of BDI-II and BAI scores, as only a small number of participants reported elevated scores. Also, BDI-II and BAI scales measure psychopathological features (i.e., depression and anxiety), while LPP amplitude does not reflect an index of psychological and neurophysiological measures in predicting higher maladaptive stress responses.

Interestingly, an opposite pattern emerged for the interaction effect between anxiety symptoms and LPP amplitude to pleasant stimuli, where pre-pandemic anxiety predicted PTSS only in individuals with low LPP amplitude to these stimuli. This finding indicates that the predisposition to avoid the seeking of positively-valenced stimuli in the environment in individuals with high anxiety could have led to greater distress during the pandemic. While the role of the Negative Valence System in anxiety is robustly consolidated, most studies disregarded the involvement of the Positive Valence System in individuals with anxiety symptoms. At the same time, although some studies reported reduced processing of pleasant and rewarding stimuli in individuals with PTSD (e.g., Nawijn et al., 2015; Kalebasi et al., 2015; Seidemann et al., 2021), it is unclear whether this effect is produced by trauma exposure or, rather, represents a vulnerability factor. Of note, the present finding suggests that the interaction between blunted processing of pleasant images and anxiety symptoms may represent a preexisting risk factor for PTSS severity.

Contrary to what was hypothesized, pre-pandemic depressive symptoms were not a significant predictor of pandemic-related PTSS. Also, no significant effect emerged for the interactions between pre-pandemic depressive symptoms and LPP to pleasant and unpleasant images. Hence, these findings indicate that depressive symptoms might not play a substantial role in conferring a higher risk to develop a maladaptive response to stressors, especially when examined alongside anxiety symptoms. Instead, the finding that pre-pandemic anxiety symptoms together with motivated attention to emotional stimuli predicted higher PTSS might be explained by the prevalent anxious features of post-traumatic stress.

At baseline, anxiety and depressive symptoms did not correlate with LPP amplitude to pleasant or unpleasant stimuli. This finding could be due to the insufficient range of variability of BDI-II and BAI scores, as only a small number of participants reported elevated scores. Also, BDI-II and BAI scales measure psychopathological features (i.e., depression and anxiety), while LPP amplitude does not reflect an index of psychopathology but the levels of motivated attention to emotional stimuli. Hence, the link between these measures may be better explained when examined in combination, as, in the present study, they potentiate one another in predicting PTSS.

Altogether, the above discussed findings indicate that, contrarily to the literature on risk factors for PTSS (e.g., Blanchard et al., 1994; Brady et al., 2000; Edmondson et al., 2014; Gulliver et al., 2021), pre-trauma anxiety and depressive symptoms did not have a direct effect in predicting PTSS. Instead, anxiety symptoms emerge as a relevant measure in the prediction of PTSS only when motivated attention to emotional stimuli is taken into account. This is crucial as it highlights the importance of combining self-report psychological measures with psychophysiological measures in the assessment of PTSS risk.

Moreover, at the subjective level, the self-assessment manikin ratings on valence and arousal demonstrated the effectiveness of the experimental manipulation. Also, unpleasant pictures were evaluated as more arousing than pleasant ones, and this is in line with other studies that reported similar results (Messerotti Benvenuti et al., 2020; Weinberg
and Hajcak, 2010). In addition, the larger LPP amplitude in response to pleasant and unpleasant than neutral stimuli demonstrates a LPP modulation to high-arousing images relative to low-arousing ones (Lang and Bradley, 2010) and it further confirms the effectiveness of the experimental manipulation.

From a clinical perspective, the present study provided novel and useful evidence for the prevention, early identification, and treatment of PTSS. Indeed, the present findings suggest that assessing anxiety symptoms and pre-trauma LPP to emotional stimuli might be a useful target for identifying individuals that are more vulnerable to the development of PTSS during times of crisis. Although traumatic events are highly unpredictable, the screening of these pre-trauma measures could be useful in several circumstances where individuals are likely to be exposed to forthcoming traumatic events, such as the military settings. Moreover, the present study might contribute to the literature attempting to develop efficient preventive interventions for PTSS, as it is currently limited (Sheffington et al., 2013). A combination of psychological interventions aimed at reducing anxiety symptoms (i.e., cognitive-behavioral therapy, Carpenter et al., 2018) together with strategies aimed at enhancing motivated attention to pleasant stimuli, while reducing motivated attention to unpleasant ones, might be suitable to prevent the presentation of PTSS in individuals with high anxiety levels that will likely be exposed to trauma. For example, attention bias modification training aimed at increasing attention towards pleasant and away from unpleasant content has been shown to improve PTSS in clinical samples (Lazarov et al., 2019; Kuckertz et al., 2014). Moreover, another suitable approach that could be useful in preventing PTSS is behavioral activation, a strategy that includes the employment of activity planning, social skills training, shaping reward, and positive imagery to increase engagement in pleasant activities. Also, meta-analytic evidence suggested that behavioral activation therapy was efficacious in decreasing PTSS in clinical samples (Etherton and Farley, 2020).

4.1. Limitations

The present findings should be considered in light of several limitations. First, the prevalence of the female sex, the relatively young age of the participants, as well as the fact that they were all enrolled in a University course and the small sample size might not allow the generalization of the findings. Second, although the IES-R has been largely employed as a measure of PTSS (e.g., Davico et al., 2021; Forte et al., 2020), the inclusion of a clinical interview might have been useful in evaluating potential clinical diagnoses. Third, PTSS were evaluated during the second wave of the pandemic in Italy, several months following the initial COVID-19 outbreak and the inclusion of multiple assessments could have been insightful in examining the trajectories of symptoms over time. However, considering that an initial but temporary stress response following a traumatic event is common (Bonanno et al., 2011; Yarrington et al., 2021), the evaluation of PTSS at a distance of almost 12 months from the pandemic outbreak was useful in isolating the effects of individuals that possibly developed prolonged maladaptive stress response.

5. Conclusions

Taken together, the present longitudinal study provided novel evidence on psychophysiological predictors of pandemic-related PTSS. In terms of the RDoC matrix, the present findings corroborate the hypothesis that an hypoactivation of the Positive Valence System and hyperactivation of the Negative Valence System may be key factors that predispose already anxious individuals to the development of PTSS.

Author contributions

C.D.A., E.D.B, T.M., S.M.B. and D.P. conceived and designed the study; C.D.A., E.D.B and S.M.B. conducted the study; C.D.A., E.D.B, T.M. and S.M.B. analyzed the data; C.D.A., E.D.B and T.M. wrote the paper, and all authors reviewed the manuscript.

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Declaration of Competing Interest

none

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jad.2022.02.027.

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