

Rapid brain responses to affective pictures indicate dimensions of trauma-related psychopathology in adolescents

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Abstract

A variety of mental disorders are related to deviant brain activity, but these neural alterations do not validate psychiatric diagnostic categories. High symptom overlap and variable symptom patterns encourage a dimensional approach. Following the logic of the Research Domain Criteria (RDoC), we investigated trauma survivors for symptom clusters that might be associated with characteristics of ERPs, in particular with the early posterior negativity (EPN) elicited during affective picture processing. In rapid serial visual presentation, 90 adolescents (40 male/50 female, age $M = 15.0 \pm 2.5$ years) who had been exposed to varying amounts of traumatic stress passively viewed a stream of high-arousing positive and low-arousing neutral pictures taken from the International Affective Picture System (IAPS). Using standardized interviews, symptoms of trauma-related mental disorders were assessed (including those for PTSD, depression, borderline personality disorder, and behavioral problems). A principal component analysis was performed to derive potential dimensions of psychopathology. Multiple regression analysis confirmed a factor comprising problems concentrating, sleeping difficulties, and mistrust as a predictor of a larger EPN difference between high-arousing positive and low-arousing neutral IAPS pictures ($\beta = 0.19$, $p < 0.05$). Sex predicted the magnitude of the EPN ($\beta = 0.45$, $p < 0.001$). Male adolescents displayed a stronger EPN suppression than female adolescents. The result suggests that problems concentrating, sleeping difficulties, and mistrust seem to be trans-diagnostic elements related to diminished early emotional discrimination represented by the EPN. Furthermore, our findings indicate that the EPN in response to emotional processing is modulated by sex.

KEYWORDS

adolescents, attention, emotion, EPN, ERP, IAPS, RDoC, trauma

1 | INTRODUCTION

Attention is primarily regulated by motivation, which is often activated by distinct unconditioned emotional stimuli. This natural selective attention (Bradley, 2009) reflects

an evolutionary inheritance. According to the motivational model of emotion (Bradley, 2009; Lang & Bradley, 2010; Lang, Bradley, & Cuthbert, 1997), stimuli with an inherent biological meaning that are significant for survival or reproduction capture attention due to their motivational relevance.

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Affects are organized around two distinct motivational sub-systems: the appetitive and the defensive system. The appetitive system is active in contexts that promote physical survival, such as ingestion, copulation, and nurturing progeny, and evoke pleasant affects. The defense system is involved in contexts that threaten survival and are associated with unpleasant affects. Both systems can vary in intensity of activation, reflecting the arousal level (Lang et al., 1997).

Using ERPs, the time course of emotional picture processing has been investigated with millisecond resolution (Hajcak, MacNamara, & Olvet, 2010; Junghöfer, Bradley, Elbert, & Lang, 2001; Keil et al., 2002; Olofsson, Nordin, Sequeira, & Polich, 2008). A relatively early processing stage reflecting the differential processing of emotional compared to neutral stimuli is the early posterior negativity (EPN). This neural activity typically observed over posterior scalp regions develops as early as 150 ms after the onset of arousing pleasant and unpleasant pictures relative to nonarousing neutral pictures and is maximally enhanced around 250–300 ms (Elbert et al., 2011). The EPN can be considered as a marker of attention allocation toward emotional material (Schettino, Keil, Porcu, & Müller, 2016) and is reliably evoked in normal individuals. It is also found in paradigms using a serial flood of discrete visual events, such as rapid serial visual presentation (RSVP; Junghöfer et al., 2001). The EPN is reported to be suppressed in individuals with various psychiatric diagnoses, including affective disorders, schizophrenia, and borderline personality disorder. It is also altered in individuals with a history of severe childhood adversities (Matz et al., 2010; Weber et al., 2009). In major depressive disorder, a reduced arousal modulation of the right temporo-parietal activation evoked by visual stimuli was found (Moratti, Rubio, Campo, Keil, & Ortiz, 2008). Modulated early visual processing of emotional stimuli was also recorded in individuals suffering from post-traumatic stress disorder (PTSD), depression symptoms, and dissociation (Adenauer, Pinosch et al., 2010; Burgmer et al., 2013; Elbert et al., 2011; Keil, Adenauer, Catani, & Neuner, 2009; Schalinski, Moran, Schauer, & Elbert, 2014). Such deviations in neural activity are assumed to be characteristic for this psychopathology. However, the conceptualization of diagnoses in the American Psychiatric Association's Diagnostic and Statistical Manual (DSM) and the International Classification of Diseases (ICD) have largely been based on subjective reports. High comorbidity among categories and an overlap of symptoms for different disorders are common. Disorders are not distinct, and the construct validity of the diagnostic concepts is disputable (Kendell & Jablensky, 2003). Hence, the National Institute of Mental Health's Research Domain Criteria (RDoC) have proposed a dimensional approach, putting forward a new research framework for interdisciplinary psychopathological research with less emphasis on traditional diagnoses and the integration of psychological and related neurobiological

systems. In the present study, an exploratory trans-diagnostic analysis is presented based on the heuristic outlined by the RDoC. Dimensions of psychopathology were investigated in adolescents who have been exposed to a varying degree of traumatic stressors such as war, violence, or childhood maltreatment.

The sample included German adolescents from both immigrant and nonimmigrant families as well as refugee youth, as these groups have been frequently exposed to severe threats and present with trauma-related symptoms (Schauer, 2016). Adolescents were chosen as they can be selected to have no history of diagnosis and treatment including psychoactive medication or drug abuse. Clinical measures included symptoms of PTSD, depression, borderline personality disorder, and behavior problems. The analysis of potential underlying dimensions was related to the response to affective picture processing in the parietal cortex. The affective RSVP design is known to produce variations with affective arousal (Junghöfer et al., 2001, 2006; Peyk, Schupp, Elbert, & Junghöfer, 2008) and was used to study participants with EEG-based assessment of regional brain activity. The cortical reaction to high-arousing pleasant pictures in comparison with low-arousing neutral pictures in an ERP study was assessed. For ethical concerns related to the age range (including adolescents at age 12 years) and the trauma history of the sample, negative valence pictures were not included. The decision was based on earlier findings (Elbert et al., 2011) that most individuals with PTSD were reminded of their traumatic experiences, even though negative valence pictures were identical for each subject and no personalized cues were presented. Thus, the negative valence stimuli turned out to be strong reminders of their traumatic experiences with the potential to induce flashbacks and should only be applied when clinically indicated. In the present study, we evaluated the association of differential cortical affective processing with potential dimensions of psychopathology. Some authors reported sex differences in affective processing including the early processing of arousing stimuli (Junghöfer, 2010; Sabatinelli, Flaisch, Bradley, Fitzsimmons, & Lang, 2004; Stevens & Hamann, 2012). Hence, the potential influence of sex was also analyzed. In particular, a reduced modulation of cortical activity to pleasant arousing pictures in the EPN window was expected to be correlated with a greater presentation of symptoms.

2 | METHOD

2.1 | Participants

This study was part of a larger research project on the trans-generational effects of stressful life events. Adolescents together with their mothers were recruited through newspaper advertisements, accommodation centers for asylum

seekers, and intercultural meeting places. Moreover, individuals who were referred to the Centre of Excellence for Psychotraumatology, University of Konstanz, by human rights organizations, social workers, medical doctors, or lawyers for diagnostic clarification were offered participation in this study in order to obtain a sample that has been exposed to traumatic stressors to a varying degree. Data were collected between January 2015 and September 2016. Exclusion criteria were neurological or psychotic disorders and current or past psychoactive medication. After the introductory phase, three subjects were not included because they felt anxious or stressed when thinking about participation, and six could not be included in the analysis due to technical failure. Included in the final data analysis were 90 adolescents ($N_{female} = 50$, $N_{male} = 40$) aged between 12 and 21 years ($M = 15.0$, $SD = 2.5$, median = 15.0). The most frequent regions of origin were Central Europe ($n = 46$), followed by the Middle East ($n = 25$) and the Balkans ($n = 11$). Seven participants originated from Asia, and one from Eastern Europe. Participants had completed 8.0 years of education ($SD = 2.64$, range = 0–13).

2.2 | Materials and procedure

After having obtained written informed consent from children and their mothers, the participants underwent an extensive standardized clinical interview administered by experienced psychologists and, if needed, with the help of trained translators. The clinical interviews were carried out prior to EEG measurement. Adolescents and their mothers were introduced to the laboratory equipment, and the task (passive viewing) was explained to them. EEG recording of all participants began with a 5- to 10-min resting period (eyes closed and eyes open measurements) followed by RSVP including 800 stimuli with 333-ms (3 Hz) presentation time per picture. The pictures were presented in four blocks of 200 pictures each. Within each block, 100 low-arousing and 100 high-arousing stimuli were presented in alternating order, whereas the type of picture varied randomly within each block and category (high and low arousal). The pictures were chosen based on normative arousal and pleasure ratings. The two categories differed significantly from each other in International Affective Picture System (IAPS) normative arousal ratings (low arousing: $M_{arousal} = 2.86$, $SD = 0.37$; high arousing $M_{arousal} = 5.67$, $SD = 0.65$). Mean valence level for the high-arousing category ($M_{valence} = 6.94$, $SD = 0.62$) was significantly higher than for the low-arousing pictures ($M_{valence} = 5.30$, $SD = 0.68$). Physical picture parameters such as brightness, contrast, color spectra, and physical complexity (JPEG file size at 90% quality) did not differ across picture categories. In each block, pictures were shown in a pseudorandom order to keep the alternation sequence constant. Participants were advised to passively view

the pictures, with their eyes focused on a small fixation cross shown at the center of the screen. Participants sat 1 m in front of the screen, which was connected to a video projection system. After recording, participants rated the affective pictures for emotional valence and arousal without time limits in a randomized picture order, using a computerized version of the Self-Assessment Manikin (SAM) self-report scale (Lang, Bradley, & Cuthbert, 2008). The affective dimensions of arousal and valence were evaluated on a 9-point scale, with higher numbers indicating an evaluation as more pleasant or arousing. All participants (mothers and adolescents) received reimbursement of their travel expenses and, if necessary, a psychodiagnostic report and arrangement of treatment (this service is offered to all referred individuals investigated at the center, irrespective of study participation). Participants were compensated 60 euros for participation in addition to their travel expenses. All experimental procedures were in accordance with the Declaration of Helsinki and were approved by the Ethics Committee of the University of Konstanz (Germany).

2.3 | Data acquisition

2.3.1 | Stimulation equipment and EEG data recording

Visual stimulation was carried out with the software Presentation (Neurobehavioral Systems, Inc.). Stimuli were presented using a PC Dell precision 390 with Intel Core TM 2CPU 2.13 Hz processor with 2 RAM. A 27.5-in. LCD visual display was used (Hanns.G HG281DJ). Electrical brain activity was monitored by a high-density, 256-channel EGI EEG system with a HydroCel Geodesic Sensor Net (Electrical Geodesics, Inc., Eugene, OR) using NetStation 4.3 on a Mac OSX with 1.25 GHz PowerPC G4 processor and 1 GB DDR SD RQM. The EEG was recorded continuously with a sampling rate of 1,000 Hz with 0.1 Hz high-pass and 400 Hz low-pass hardware filters and the vertex (Cz) electrode as reference. Electrode impedances were kept below 30 k Ω .

2.3.2 | Psychopathological symptoms

Depression symptoms were assessed using the Patient Health Questionnaire (PHQ; Kroenke, Spitzer, & Williams, 2001). The PHQ-9 rates each of the nine DSM-IV criteria on a 4-point Likert scale from 0 (*not at all*) to 3 (*almost every day*). Scores were summed, with a possible maximum of 27 ($M = 4.33$, range = 0–21, $SD = 5.46$). With its very good psychometric properties, the PHQ-9 can establish the diagnosis of major depressive disorder according to DSM-IV (Gilbody, Richards, Brealey, & Hewitt, 2007). Cronbach's alpha was 0.91 for the current study. The number of types of traumatic experiences was examined by the Event List

of the Posttraumatic Diagnostic Scale (Foa, Cashman, Jaycox, & Perry, 1997). Items were coded dichotomously (yes, no) and summed up to produce a score between 0 and 12 ($M = 2.14$, range = 0–10, $SD = 2.15$). The German translation of the PTSD Symptom Scale Interview Version (PSS-I; Ehlers, Steil, Winter, & Foa, 1996; Foa, Riggs, Dancu, & Rothbaum, 1993) was administered in order to assess PTSD symptom severity according to DSM-IV criteria (American Psychiatric Association, 2000). The scale consists of 17 items on a 4-point Likert scale (Foa et al., 1993). Each item refers to one symptom of PTSD grouped into the three symptom clusters (intrusion, avoidance, hyperarousal). Items were summed to produce a score between 0 and 51 ($M = 5.18$, range = 0–38, $SD = 8.06$). The PSS-I has proven to be a valid and reliable instrument (Foa & Tolin, 2000). For the present study, Cronbach's α was 0.93. Borderline symptoms were assessed using the German version of the Borderline Symptom List-23 (BSL-23; Bohus et al., 2009). Its 23 items are scored on a 5-point Likert scale ranging from 0 to 4 (0 = *not at all*, 4 = *very strongly*) depending on their applicability for the last week. Excellent psychometric properties have been published (Bohus et al., 2009). A severity sum score ranging from 0 to 92 can be calculated ($M = 9.36$, range = 0–43, $SD = 12.17$), with scores ≥ 64 (76th percentile) indicating clinically relevant symptom levels (Bohus et al., 2009). Cronbach's α coefficient for this sample was 0.92. Behavioral problems over the 6 months preceding the interview were screened using the German self-reported version of the Strengths and Difficulties Questionnaire (SDQ; Goodman, Meltzer, & Bailey, 1998; Klasen et al., 2000). On a three-stage scoring (0 = *not true*, 1 = *somewhat true*, 2 = *certainly true*), 20 items were summed to gain a total difficulties score indicating the severity and the content of the psychosocial problems, with a maximum possible score of 40. The reliability and validity of the total difficulties score is reported to be satisfactory (Lohbeck, Schultheiß, Petermann, & Petermann, 2015). In our sample, the Cronbach's α for the total difficulties score was 0.79. The average total difficulties score was 11.65 (range = 2–30, $SD = 6.63$). Based on the heuristic outlined by the RDoC, an exploratory transdiagnostic analysis was performed using the intercorrelated sum scores of the instruments, which are described above. Principal component analysis (PCA) was used due to the primary purpose of identifying factors underlying these instruments.

2.4 | Data analysis

2.4.1 | SAM ratings

SAM arousal and valence ratings were analyzed using IBM SPSS Statistics Version 24 for Mac in separate repeated

analyses of variance (ANOVAs), with sex as the between-subjects factor and stimulus category (low arousing, high arousing) as the within-subject factor.

2.4.2 | EEG data analysis

ERP analysis

Epochs of 500 ms pre- to 500 ms poststimulus onset were extracted from the continuous data using the MATLAB-based toolbox FieldTrip (Oostenveld et al., 2011). All trials per condition were retained in subsequent analyses. Data were band-pass filtered using a sine windowed finite impulse response filter 0.540 Hz (Widmann, Schröger, & Maess, 2015). Subsequently, the data were resegmented into epochs of 0 to 300 ms after the stimulus onset. This ensured that potential filtering artifacts remained outside of the analysis time window of interest. No baseline correction was applied. Average ERPs for the low-arousing and high-arousing picture category were calculated for each electrode. Analysis focused on the interval from 0 to 300 ms after stimulus onset, including the window of the EPN reported in Junghöfer et al. (2001), Peyk et al. (2008), and Schupp Flaisch Stockburger and Junghöfer (2006).

Source analysis

Source estimates were computed by applying a time domain adaptive spatial filtering algorithm (linearly constrained minimum variance; Van Veen, van Drongelen, Yuchtman, & Suzuki, 1997). This algorithm uses the covariance matrix from the EEG data and the lead field derived from the forward model to construct a spatial filter for a specific location (voxel). These spatial filters were estimated on the basis of all trials (pooling high- and low-arousing conditions). A single standard anatomical MRI and standard digitized electrode positions were coregistered to a common coordinate system (Montreal Neurological Institute, MNI) by applying an initial coarse registration between the fiducial locations (nasion and left and right preauricular points) and subsequently refined matching between the scalp surface extracted from the standard MRI and the standard digitized electrode positions. A three-compartment (skin, skull, brain) pseudorealistic boundary-element forward solution was constructed on the basis of a standard MRI (MNI152 linear template) and applied to all participants.

Statistical analysis

Quantification of time domain condition differences was carried out using a cluster-based approach based on randomizations (Maris & Oostenveld, 2007). This approach identifies clusters of activity (in time and space, i.e., electrodes or voxels) on the basis of which the null hypothesis that the data in the high- and low-arousing conditions is exchangeable can be rejected, while addressing the multiple-comparison

problem (Maris & Oostenveld, 2007). Clusters of electrodes were identified as differentially active when the difference between stimulus categories exceeded a threshold of significance at the 5% level. Via 1,000 random permutations of the data, the cluster level statistic was defined as the sum of t values within each cluster containing at least five adjacent electrodes. The null hypothesis probability (no difference between stimulus categories) of observing a maximum (minimum) cluster-level statistic larger (smaller) than the observed cluster-level statistic is indexed by the obtained p values. This procedure was applied to both sensor and source-level evaluation. Mean EPN values were extracted per condition per subject from posterior electrode clusters judged representative after cluster-based evaluation. The relative difference potential (high-arousing amplitude minus low-arousing amplitude) was calculated as a measure of EPN for further analyses.

2.4.3 | PCA

A PCA with orthogonal rotation (varimax) was conducted on the 55 items of the questionnaires (BSL-23, SDQ, PHQ-9) and the 17 items of the interview (PSS-I). Initially, the factorability of the items was examined. Several well-recognized criteria for the factorability of a correlation were used. Variables with diagonal anti-image correlations of less than 0.6 were excluded from the analysis. Values less than 0.6 indicate that the sampling is not adequate (Cerny & Kaiser, 1977; Dziuban & Shirkey, 1974). It was observed that all remaining items correlated at least 0.3 with at least one other item, suggesting reasonable factorability. The Kaiser-Meyer-Olkin measure (KMO) of sampling adequacy was 0.84 (“superb” according to Field, 2009) and all KMO values for individual items; the diagonals of the anti-image correlation matrix were also all over 0.6. Bartlett’s test of sphericity was significant ($\chi^2(630) = 2,412.95, p < 0.001$) indicating that correlations between items were sufficiently large for PCA. Finally, the communalities were all above 0.4, further confirming that each item shared some common variance with other items. Given these overall indicators, factor analysis was deemed to be suitable, with 36 items.

2.4.4 | Association between EPN and behavioral data

To test the relationship between the factors of the PCA and the EPN, a multiple sequential regression analysis was conducted. Sex was included as a possible confounding variable, as substantial gender differences were found in emotional processing (Stevens & Hamann, 2012). After controlling for the influences of sex and age, the PCA factors and the number of traumatic events experienced were added to the model. The regression model fulfilled all necessary quality

criteria for linear regression analyses. The residuals of the regression analysis were normally distributed and independent; assumptions of homoscedasticity and linearity were met. Multicollinearity was of no concern. All analyses were two-tailed and based on $\alpha = 0.05$ level of significance. Our metric for a small effect size was $f^2 \geq 0.02$, for a medium effect, $f^2 \geq 0.15$; and for a large effect, $f^2 \geq 0.35$. Data were analyzed using IBM SPSS Statistics Version 24 for Mac.

3 | RESULTS

3.1 | Behavioral data

Sample characteristics are shown in Table 1. Participants were exposed to a broad range of 0 to 10 different traumatic event types ($M = 2.14, SD = 2.15$). Sex differences were found for PHQ-9 and BSL-23 scores only. Female participants reported higher depression symptoms ($M = 5.4, SD = 5.95$) than male ($M = 2.7, SD = 4.02; t(88) = -2.42, p < 0.05$) and also higher borderline symptoms ($M = 12.97, SD = 13.58$) than male ($M = 4.84, SD = 1.33; t(88) = -3.31, p < 0.01$). Eighteen percent ($n = 16$) of adolescents fulfilled a PTSD diagnosis according to DSM-IV. With respect to borderline symptoms (BSL-23), none of the participants reached a diagnostically relevant symptom score. A total of 28% ($n = 25$) showed elevated behavioral difficulties according to SDQ.

3.2 | Validation of paradigm

3.2.1 | Affective ratings

Figure 1 presents the box plot of the arousal and valence ratings separately for male and female adolescents. There was no main effect of and/or interaction with sex, indicating similar evaluations of valence and arousal scores of the pictures in female and male participants. As expected, the arousal ratings differed as a function of affective category,

TABLE 1 Subjectively reported symptoms of the study group

Measure	<i>M</i>	<i>SD</i>	<i>Mdn</i>	Range
Depression (PHQ-9)	4.33	5.46	2.00	0–21
PTSD symptoms (PSS-I)	5.18	8.06	0.00	0–38
Traumatic event types (PSS-I)	2.14	2.15	1.00	0–10
Borderline symptoms (BSL-23)	9.36	12.17	4.00	0–43
Behavioral difficulties (SDQ)	11.65	6.63	10.83	2–30

Note. *M* = mean; *SD* = standard deviation; *Mdn* = median. *N* = 90.

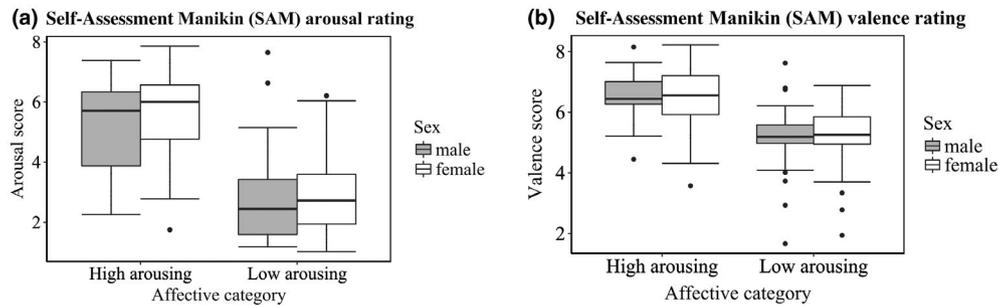


FIGURE 1 Self-Assessment Manikin (a) arousal and (b) valence ratings of male and female adolescents as a function of picture categories (low-arousing, high-arousing pictures; possible values range from 1 to 9 for arousal and for valence). The box frames the lower and upper quartile; line inside the box indicates the median; upper and lower whiskers indicate variability outside the lower and upper quartiles; circles illustrate outliers

$F(1, 88) = 181.53, p < 0.001$, partial $\eta^2 = 0.71$, with high-arousing pictures rated as more arousing than low-arousing pictures. Valence ratings for all participants also varied across picture categories, $F(1, 88) = 85.66, p < 0.001$, partial $\eta^2 = 0.53$, with high-arousing pictures rated as more pleasant than low-arousing pictures. Examining correlations and scatter plots, we found that SAM ratings were not related to age. These results indicate that arousal ratings of male and female participants varied, as reported in Lang et al. (2008), depending on the affective category of the stimuli.

3.2.2 | EPN

The early selective processing of high-arousing pleasant stimuli was associated with stronger negativity (i.e., less positivity, Figure 2a) over bilateral parieto-occipital electrodes than low-arousing stimuli (Figure 2b). A pronounced ERP difference for the processing of low-arousing and high-arousing pleasant pictures developed around 150 ms, which was maximally pronounced around 200–300 ms (Figure 1a,b, $p < 0.001$, nonparametric cluster permutation test). Source analysis revealed cortical generators in the right parieto-occipital cortex (Figure 2c).

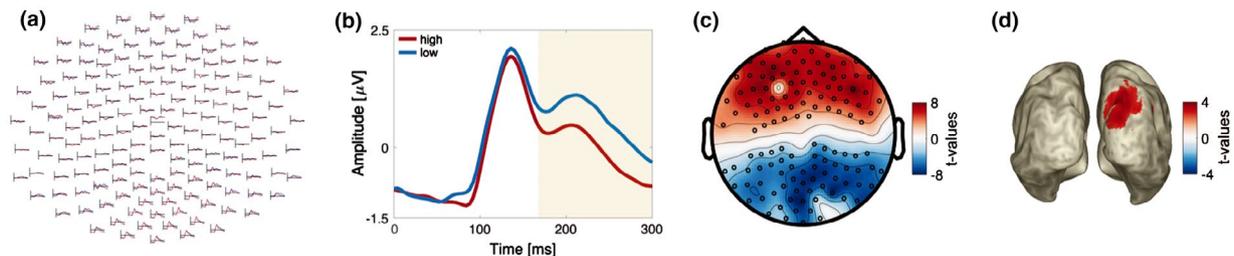


FIGURE 2 (a) Multichannel representation of the ERP split by condition: high arousing (red) and low arousing (blue). (b) ERPs illustrating brain responses during high- (red) and low- (blue) arousing conditions averaged over posterior cluster of electrodes depicted in (c). Shading background highlights the EPN. (c) Topography of the high minus low contrast expressed in units of t values. Circles highlight electrodes belonging to clusters confirming significant condition differences ($p < 0.001$). (d) Source-level high minus low contrast corresponding to the topography in (c). The inflated brain surface is shown from the back of the head highlighting the areas of occipital and parietal cortex. Note that (c) and (d) present statistical maps for the difference and not one of the electric potential or its differences

3.3 | Dimensions of psychopathology

The PCA produced eight factors with eigenvalues greater than 1. The inflexion point of the scree plot (Cattell, 1966) occurred at the fifth eigenvalue. The five-factor solution, which explained 61% of the variance, was preferred because of the “leveling off” of eigenvalues on the scree plot after five factors as well as the insufficient number of primary loadings and difficulty of interpreting the subsequent factors. Factors I, II, III, IV, and V accounted for 14%, 14%, 13%, 7%, and 6% of the variance in the behavioral data, respectively. The last dimension of psychopathology, Factor V, implies motoric disquiet. Table 2 lists factor loadings after rotation. Internal consistency for each of the factors was examined using Cronbach’s α . Representing dimensions of psychopathology, the five factors proved to be legitimate clinical variables for further analyses.

3.4 | Dimensions of psychopathology and EPN

As displayed in Table 3, Factor II yielded modest and Factor III moderate correlations with EPN suppression. In addition, the number of experienced traumatic events was found to

TABLE 2 Summary of items and factor loadings for varimax orthogonal five-factor solution

Questionnaire	Item	Factor loading
Factor I ($\alpha = 0.89$)		
PSS-I	Unwanted distressing memories about the trauma	0.83
PSS-I	Being emotionally upset when reminded of the trauma	0.77
PSS-I	Having physical reactions when reminded of the trauma	0.74
PSS-I	Efforts to avoid thoughts or feelings related to the trauma	0.66
PSS-I	Efforts to avoid activities, situations, or places that remind you of the trauma	0.64
Factor II ($\alpha = 0.84$)		
BSL	Feeling lonely	0.73
PHQ	Feeling bad about yourself or that you are a failure or have let yourself or your family down	0.68
PHQ	Feeling tired or having little energy	0.61
PHQ	Trouble falling or staying asleep, or sleeping too much	0.61
Factor III ($\alpha = 0.88$)		
BSL	Not trusting other people	0.81
PHQ	Trouble concentrating on things, such as reading the newspaper or watching television	0.76
PSS-I	Difficulties falling or staying asleep	0.66
BSL	Hard concentrating	0.63
PSS-I	Having difficulties concentrating	0.61
Factor IV ($\alpha = 0.76$)		
SDQ	Being often accused of lying or cheating	0.81
PSS-I	Acting more irritable or aggressive	0.66
PSS-I	Feeling as if your future plans or hopes will not come true (e.g., you will not have a career, marriage, children, or a long life)	0.61
Factor V ($\alpha = 0.82$)		
SDQ	Constantly fidgeting or squirming	0.81
SDQ	Being restless, unable to stay still for long	0.79

Note. Items are grouped by proposed factor assignment and listed by factor loading size in descending order. $N = 90$.

TABLE 3 Correlations between variables

Measure	1	2	3	4
1. Δ EPN				
2. Age	0.22*			
3. Sex	0.49**	0.24*		
4. No. of traumatic events	0.25*	0.13	-0.02	
5. Factor I	0.19	0.07	0.12	0.33**
6. Factor II	0.22*	0.09	0.09	0.24**
7. Factor III	0.30**	0.11	0.12	0.27**
8. Factor IV	-0.03	-0.04	-0.16	0.42**
9. Factor V	0.01	-0.25*	-0.21	0.08

Note. Pearson correlations were calculated. Δ EPN = relative difference potential (high-arousing amplitude minus low-arousing amplitude). Significant correlations are printed in bold.

* $p < 0.05$ ** $p < 0.01$.

be negatively associated with the EPN in the visual cortex. The first regression model with sex and age as predictors explained 24% of the variability of the EPN ($R_{adj}^2 = 0.24$, $F(2, 87) = 14.67$, $p < 0.001$, $f^2 = 0.32$). The inclusion of Factors II and III along with the experienced events as additional predictors improved the model significantly, $F(3, 84) = 4.87$, $p < 0.01$, $f^2 = 0.47$. This updated model explained 33% of the variance. Because of the inherent associations between experiencing traumatic stress and psychopathology, the number of experienced traumatic events as a potential modulator of affective processing was included in the analysis. Results are presented in Table 4. Factor III was associated with EPN suppression, whereas the number of experienced traumatic events was not a significant predictor. The total regression model explained 32% of the variability of the EPN. Adding interaction terms or controlling for ethnicity did not improve the model in terms of higher variance explained, and significance was not reached. Thus, problems concentrating,

TABLE 4 Results of regression analysis predicting EPN

Predictor variables	Early posterior negativity			
	<i>B</i>	<i>SE of B</i>	β	<i>T</i>
Step 1				
Sex	7.18	1.47	0.46	4.87***
Age	0.37	0.30	0.11	1.23
Step 2				
Sex	6.93	1.41	0.45	4.93***
Age	0.21	0.29	0.07	0.74
Factor II	0.95	0.71	0.12	1.34
Factor III	1.50	0.71	0.19	2.11*
No. of traumatic events	0.63	0.34	0.17	1.82

Note. The constant is not shown for a better readability. $R_{adj}^2 = 0.32$; $f^2 = 0.47$; *B* = unstandardized regression weight; *SE* = standard error; β = standardized regression weight; *T* = *t*-test statistics. *N* = 90.

* $p \leq 0.05$ *** $p \leq 0.001$.

sleeping difficulties, and mistrust (Factor III) showed to be related to EPN suppression. Figure 3 shows the relation between Factor III and EPN suppression for male and female adolescents.

4 | DISCUSSION

The currently used classification systems (DSM, ICD) have largely been based on subjective reports, and the diagnostic categories (but not necessarily the symptoms) lack validation from neurosciences, genetics, or other biological investigations. In order to provide a framework for translational research of mental disorders, the RDoC project was launched, incorporating psychological and related neurobiological systems (Cuthbert & Insel, 2013). Therefore, the aim of this

study was to apply a trans-diagnostic approach following the logic of RDoC and examine the association between dimensions of psychopathology and affective picture processing as measured by the ERP method. As expected, our findings confirm an arousal-driven modulation of affective picture processing in adolescents during the EPN interval, as discovered by Junghöfer et al. (2001) for adults and Wessing, Fürniss, Zwitterlood, Dobel, and Junghöfer (2011) for 8- to 10-year-old children. Arousing pleasant stimuli evoked a more negative amplitude deflection over posterior brain regions 150 to 300 ms after stimulus onset than did low-arousing stimuli even using RSVP, meaning that the EPN can be recorded for briefly presented stimuli that are shown at a rapid rate. Our results support the notion of EPN being a well-founded neural correlate of affective stimulus discrimination (Junghöfer et al., 2001, 2006; Olofsson et al., 2008; Peyk et al., 2008; Schupp, Junghöfer, Weike, & Hamm, 2004). Likewise, these findings are in line with the concept of natural selective attention (Bradley, 2009), as the perceptual processing of emotional stimuli seems facilitated. However, prior work has shown that ERPs during affective processing can be deviant in individuals with psychiatric disorders (Adenauer, Pinosch et al., 2010; Burgmer et al., 2013; Elbert et al., 2011; Felmingham, Bryant, & Gordon, 2003; Holmes, Nielsen, & Green, 2008; Kemp et al., 2009; Matz et al., 2010; Rockstroh, Junghöfer, Elbert, Buodo, & Miller, 2006; Weber et al., 2009). In the current study, psychopathological symptom clusters were identified using PCA. Interestingly, the factor comprised of problems concentrating, sleeping difficulties, and mistrust was associated with a reduced affective distinction between high-arousing and low-arousing pictures. Within a similar time interval, further studies have also found reduced posterior discrimination in response to affective faces (Chu, Bryant, & Gatt, 2016; Felmingham et al., 2003), affective pictures (Matz et al., 2010; Weber et al., 2009), or

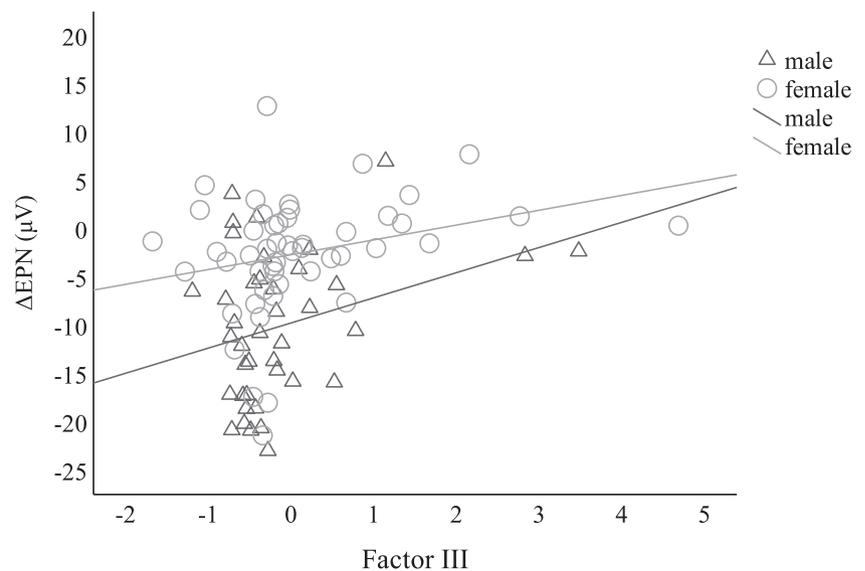


FIGURE 3 Scatter plot of Factor III and Δ EPN with separate fitted linear regression lines for male and female adolescents

words (Kounios et al., 1997) in trauma-related psychopathology. Much clinical research has focused on emotional processing of aversive material. Our result provides additional support for EPN suppression also using pleasant emotional material. This matches well with Adenauer, Pinosch et al. (2010) and Burgmer et al. (2013), confirming a reduced differential responding not only to unpleasant, but also to pleasant visual stimuli in PTSD.

Sex was found to modulate emotional processing, as male adolescents displayed a stronger affective differentiability in our study. A meta-analysis of neuroimaging studies (Stevens & Hamann, 2012) confirmed sex as a potential factor modulating emotional processing. In accordance with our study, Stevens and Hartman found male participants to be more responsive to pleasant emotional material than female. In particular, stress symptoms such as problems concentrating, sleeping difficulties, and mistrust (Factor III) might influence affective processing modes, as stress has been found to influence stress-sensitive systems such as the hypothalamus-pituitary-adrenal (HPA) axis (Champagne et al., 2008; Lo Iacono & Carola, 2018; Lupien, McEwen, Gunnar, & Heim, 2009; McEwen, 2004; Smith & Vale, 2006; Ulrich-Lai & Herman, 2009). Hence, emotion-modulated psychophysiological responses (Adenauer, Catani, Keil, Aichinger, & Neuner, 2010; Niermann et al., 2017) and affective processing seem to be altered. Reduced brain response indicated by EPN suppression might also reflect neuronal plasticity, an adaptation of the neuronal system to stress-induced conditions (Berlucchi & Buchtel, 2009; Duman, 2004; Power & Schlaggar, 2017). Correspondingly, research demonstrated gray matter abnormalities in primary and secondary visual cortices (Tomoda, Navalta, Polcari, Sadato, & Teicher, 2009) as well as in regions involved in affect control (Lim, Radua, & Rubia, 2014) in individuals with a history of early life stress. Mueller-Pfeiffer et al. (2013) also reported a diminished neural activity in the visual system in PTSD patients. Likewise, studies have reported white matter abnormalities, suggesting alterations in neural pathways (Akiki, Averill, & Abdallah, 2017; O'Doherty et al., 2018). An alternative explanation for the EPN inhibition might be an adaptive adjustment of emotion processing to arousing material after experiencing traumatic stress with a subsequent heightened arousal state. Our findings indicate that the ability to modulate arousal-related cortical structures to emotionally visual content seems impaired when problems concentrating, sleeping difficulties, and mistrust are present.

Some limitations of the current study need to be considered: For ethical concerns, no negative valence pictures were presented to adolescents in our lab. The present EPN effect might have been driven by overlapping valence and arousal characteristics. Furthermore, data are cross-sectional and hence correlational in nature, precluding determination of causality. The sample comprised adolescents from diverse ethnic backgrounds and represented a broad age range. This

may have increased the variability, and thus effects may have gone undetected. However, the observed effects seem to hold across this broad range. The ethnic background varied greatly so that it cannot have systematically confounded the outcome. However, it may well be possible that this increased “noise” in the dependent variables. Moreover, symptom levels of the majority of participants were low, which may have contributed to low correlations. In our data, at least the first two factors of the PCA seem to reflect the instruments used. It is not possible to assess the full spectrum of potential psychopathology in such a study. Regarding the RDoC framework, one might argue that a discrete domain was not assessed. However, RDoC suggests expanding analysis beyond categorical diagnoses by classifying dimensions of behavior and including other units of analyses such as circuits or physiology. Using PCA to ground self-reported symptoms in biological phenomena can be seen as exploratory trans-diagnostic analysis based on the RDoC heuristic.

In sum, we suggest that problems concentrating, sleeping difficulties, and mistrust seem to be common trans-diagnostic elements related to a reduced early affective discrimination represented by the EPN. These findings furthermore extend those of prior research on emotional processing in trauma survivors (Adenauer, Pinosch et al., 2010; Burgmer et al., 2013; Elbert et al., 2011; Felmingham et al., 2003), confirming that EPN suppression can also be found in adolescents. We conclude that stress symptoms might induce the functional reorganization of the emotional processing streams and may be reflected in dampened cortical affective differentiability to emotional stimuli.

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