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Processing of affective words in adolescent PTSD—Attentional bias toward social threat

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Abstract

Post-traumatic stress disorder (PTSD) is associated with a hypersensitivity to potential threat. This hypersensitivity manifests through differential patterns of emotional information processing and has been demonstrated in behavioral and neurophysiological experimental paradigms. However, the majority of research has been focused on adult patients with PTSD. To examine possible differences in underlying neurophysiological patterns for adolescent patients with PTSD after childhood sexual and/or physical abuse (CSA/CPA), ERP correlates of emotional word processing in 38 healthy participants and 40 adolescent participants with PTSD after experiencing CSA/CPA were studied. The experimental paradigm consisted of a passive reading task with neutral, positive (e.g., *paradise*), physically threatening (e.g., *torment*), and socially threatening (i.e., swearing, e.g., *son of a bitch*) words. A modulation of P3 amplitudes by emotional valence was found, with positive words inducing less elevated amplitudes over both groups. Interestingly, in later processing, the PTSD group showed augmented early late positive potential (LPP) amplitudes for socially threatening stimuli, while there were no modulations within the healthy control group. Also, region-specific emotional modulations for anterior and posterior electrode clusters were found. For the anterior LPP, highest activations have been found for positive words, while socially and physically threatening words led to strongest modulations in the posterior LPP cluster. There were no modulations by group or emotional valence at the P1 and EPN stage. The findings suggest an enhanced conscious processing of socially threatening words in adolescent patients with PTSD after CSA/CPA, pointing to the importance of a disjoined examination of threat words in emotional processing research.

KEYWORDS

abuse, adolescents, EEG, emotional information processing, ERP, post-traumatic stress disorder, words

1 | INTRODUCTION

Post-traumatic stress disorder (PTSD) is a disorder that may occur after the experience of a traumatic, life-threatening event (e.g., physical or sexual assault, combat, or natural disasters). Researchers attribute the core features of PTSD (avoidance, negative alterations in cognition and mood, re-experiencing, and alterations in arousal and reactivity; American Psychiatric Association, 2013) to a number of disturbed dysfunctional cognitive systems, such as altered attention, perception, memory, and judgment (Johnson, Bomyea, & Lang, 2016). The presumed importance is also reflected by popular theoretical models of PTSD, which include distinct cognitive processing as a fundamental part of development and maintenance of PTSD (Brewin, Dalgleish, & Joseph, 1996; Ehlers & Clark, 2000; Foa, Steketee, & Rothbaum, 1989). Psychophysiological research could provide evidence for increased amygdala activation and decreased activation in prefrontal cortical areas as well as reduced hippocampal volumes in PTSD (Etkin & Wager, 2007), leading to a supposedly over-reactive threat detection (amygdala: e.g., Phelps, 2004; Vuilleumier, 2005), possibly diminished regulatory control (prefrontal cortex: e.g., Kane & Engle, 2002), and disrupted adaptive memory processes (hippocampus: e.g., Furini, Myskiw, & Izquierdo, 2014).

While increased attentional focus to possibly threatening stimuli is consistently demonstrated for anxiety disorders (e.g., Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007), findings for PTSD have been shown to be inconsistent with respect to the direction of the attentional bias for threatening stimuli. For example, in an eye-tracking study with war veterans, the authors found indications for a hypervigilance toward threatening pictures (Kimble, Fleming, Bandy, Kim, & Zambetti, 2010). On the other hand, there are studies using different methodologies (e.g., magneto-encephalogram [MEG] and flickering aversive pictures: Catani, Adenauer, Keil, Aichinger, & Neuner, 2009; EEG and affective facial expressions: Felmingham, Bryant, & Gordon, 2003), which argue for a decreased visual processing of aversive stimuli in PTSD. The variability of reported attentional biases seems to be particularly empirically observable in PTSD (Naim et al., 2015) and may be associated with differences in traumatic events, PTSD severity, or type of examined sample (e.g., adults vs. adolescents).

One possible way to integrate the seemingly conflicting findings is the so-called hypervigilance-avoidance processing pattern. In this framework, anxious as well as traumatized individuals tend to exhibit a rapid early response to aversive cues, followed by an attentional avoidance that may lead to a weakened psychophysiological fear reaction (Koster, Verschuere, Crombez, & Van Damme, 2005; Mogg, Bradley, Miles, & Dixon, 2004; Pflugshaupt et al., 2005). For PTSD, this pattern may reflect an adaptive process in cortical processing in individuals who have been severely traumatized in the past.

After experiencing life-threatening events, individuals may develop a rapid threat-detection process that helps to quickly identify danger in the environment. Such a process may serve to reduce the risk of retraumatization in a high-threat environment but may also limit the amount of attention allocated to stimuli identified as threatening. Accordingly, further attention is unnecessary once the determination has been made that a stimulus is categorized as dangerous, as this additional processing may inhibit the initiation of the flight reaction, putting the individual at risk when danger may be imminent (Adenauer et al., 2010). However, depending on the involved methodologies and paradigms, there are also studies that could only find indications for hypervigilance but not the proposed subsequent avoidance pattern. In a meta-analysis by Shvil, Rusch, Sullivan, and Neria (2013), the authors argue that findings regarding attentional bias abnormalities in PTSD may in part be associated with the specific task and environment of the study. Different results have been found for naturalistic versus laboratory setups or the use of trauma-related threatening versus unrelated threatening stimuli. Nevertheless, in comparison with non-PTSD control groups, individuals with PTSD largely seem to exhibit hypervigilant attention toward threat cues (Shvil et al., 2013).

In order to understand the details of information processing, measurements of ERPs can provide valuable insights into the idea of a biphasic attentional bias in PTSD. In studies with healthy individuals, possible modulatory effects of emotionally valent information during early (e.g., P1, early posterior negativity [EPN]) and later (e.g., P3, late positive potential [LPP]) stages of information processing have been examined. Negative as well as threatening content has been associated with augmented early ERP components such as the P1 or the EPN and also with later processing steps, prominently represented by the P3 or the LPP. For a thorough discussion of this topic, see reviews by Schupp, Flaisch, Stockburger, and Junghöfer (2006) and Olofsson, Nordin, Sequeira, and Polich (2008). In order to disentangle information processing abnormalities in PTSD, studies have attempted to find possible biomarkers in the established ERP components by comparing individuals suffering from PTSD with healthy controls.

One of the most frequently reported biomarkers for PTSD is the P3 component, a large positive EEG deflection that has been associated with the level of tonic arousal and phasic alterations in arousal to specific events (Polich & Kok, 1995) and typically peaks between 300 and 400 ms (Polich, 2007). It is also often associated with the allocation of attentional resources in PTSD (McFarlane, Weber, & Clark, 1993). The P3 component is often researched using either visual or auditory oddball paradigms (Javanbakht, Liberzon, Amirsadri, Gjini, & Boutros, 2011). In the review by Javanbakht et al., the majority of included studies found reduced P3 response

amplitudes for target stimuli in participants with PTSD. In visual studies, the paradigms mostly examined P3 responses to trauma-relevant versus nonrelevant or neutral stimuli. Most studies reported increased amplitude to trauma-relevant stimuli and diminished responses to neutral stimuli in participants with PTSD. For example, Attias, Bleich, Furman, and Zinger (1996) examined veterans using a visual oddball task with animal, furniture, and war-related pictures. The authors reported enhanced early (N1) as well as later (P3) amplitudes in the PTSD group for trauma-related (war) pictures. In a word-processing oddball study, Stanford and colleagues (Stanford, Vasterling, Mathias, Constans, & Houston, 2001) demonstrated attenuated P3 responses to neutral stimuli in veterans with PTSD. To sum up, it is not fully understood yet if PTSD leads to generally (vs. valence-specific) attenuated or diminished P3 levels in PTSD. The present findings, however, mostly support the hypothesis of a hypersensitivity to trauma-related stimuli and a dampened processing of neutral stimuli at P3 stage (Javanbakht et al., 2011).

In the context of neurobiological correlates of emotional information processing, the LPP is another widely studied component. It appears approximately 400 ms after stimulus onset and is understood as a means of tracking motivated attention toward emotionally salient information (Hajcak, MacNamara, Foti, Ferri, & Keil, 2013). Contrary to its apparent importance in regard to possible abnormalities in emotional information processing, few studies have examined the LPP as a biomarker for PTSD. In a study with combat veterans, MacNamara and colleagues (MacNamara, Post, Kennedy, Rabinak, & Phan, 2013) found reduced LPP amplitudes for patients with PTSD during the processing of angry facial expressions. In a recent study by DiGangi et al. (2017), veterans with PTSD exhibited blunted LPP reactivity when being confronted with emotional facial expressions (across all emotion types). Interestingly, high postdeployment stress in veterans without PTSD was associated with enhanced LPP reactivity across all emotion types. While there is still a need for further research to form a more definite picture, the mentioned results are indicative of an avoidance pattern in the later information processing steps in patients with PTSD.

The majority of research regarding PTSD characteristics has been carried out in adult populations (e.g., combat veterans). Given the high prevalence rates of CSA and the related risk of developing PTSD after suffering from CSA/CPA, there is a need to extend the focus of research to younger, adolescent populations (Rosner, König, Neuner, Schmidt, & Steil, 2014). This may be beneficial for understanding the specific needs for adapted treatment in adolescents with PTSD after CSA/CPA. Moreover, it seems necessary to examine adolescent emotional information processing in PTSD in order to compare the results with existing results found in adult populations.

Childhood sexual abuse is an interpersonal trauma, which includes the violation of the victim's personal and physical integrity. As a result of CSA, it seems obvious that the subsequent fear network of the victim includes not only triggers that indicate physical threat, but also signs of interpersonal threat. Likewise, this seems to be true for physical abuse, which may co-occur with facets of humiliation and verbal insults. Most of the studies that examined physiological reaction patterns to either threat-related or threat-provoking affective stimuli mainly used pictures, faces, or sounds. However, there are many studies that could show that affective words are also able to modulate emotional processing in terms of altered psychophysiological reactions (e.g., EPN modulations: Herbert, Junghofer, & Kissler, 2008; Kissler, Herbert, Peyk, & Junghöfer, 2007, 2009).

In emotional word processing research, stimulus categories are often defined by arousal and emotional valence (Citron, 2012). However, the studies mostly do not distinguish between different types of negative emotional words. While some authors argue that neuronal and physiological changes in emotional word processing are mainly driven by the arousing content of a stimulus, irrespective of its actual valence (Hofmann, Kuchinke, Tamm, Võ, & Jacobs, 2009), there is reason to assume distinct responses for swear words that may represent a special type of negative word. First, swear words are usually directly addressed to a recipient and may therefore be automatically perceived with a stronger self-reference by a reader than other emotional nouns or adjectives. In line with this, prior studies were able to show significant impact of the self-relevance of a stimulus on EPN and LPP modulation (neutral faces: Klein, Iffland, Schindler, Wabnitz, & Neuner, 2015). Additionally, in the context of emotional word processing, Herbert, Pauli, and Herbert (2011) reported augmented LPP amplitudes for self-related negative nouns only. Negative valence, however, was associated with more pronounced ERPs at EPN stage, regardless of self-relevance. Second, while many studies use stimuli that convey some sort of physical threat (i.e., pain, sorrow, violence), swear words have a strong social connotation. Research from the field of social exclusion indicates that socially threatening situations may lead to intense emotional, behavioral, and physiological stress responses (MacDonald & Leary, 2005). The authors argue for a specificity of social stress situations that may (at least partly) differ from situations with physical threat. This argument may especially be valid for subjects with PTSD after CSA/CPA. With respect to the potentially diverse history of traumatization by physical and social threat, here, socially threatening words may be associated with peri-traumatic experiences and therefore suitable to evoke differential processing in the PTSD group. In order to cover the impact of social as well as physical threat in a sample with PTSD after CSA/CPA, we therefore tried to distinguish between

physically threatening and socially threatening words, the latter represented by swear words.

The aim of the present study was to examine whether PTSD after CSA/CPA in adolescent participants is associated with an altered pattern of emotional information processing as has been reported in adult PTSD samples. With respect to the presented literature, we particularly sought to investigate ERP modulations in later stages of emotion processing (i.e., P3 and LPP). Here, we assumed differences between participants with PTSD and healthy controls, with amplitudes within the PTSD group being distinctively modulated by threat-related stimuli (socially and physically threatening). In order to test our hypothesis, we exposed adolescent participants with PTSD after CSA/CPA to emotionally valenced words and compared the information processing patterns with a healthy adolescent sample.

Although the principal aim of the present study was to investigate later stages of information processing, additional analyses examined potential differential modulations of the P1 (~100 ms poststimulus) and EPN (~200–300 ms poststimulus). Because previous studies indicated that processing of emotional words was associated with early visual processing steps (Hofmann et al., 2009; Sass et al., 2010), we explored whether P1 modulations were also induced by the emotional words used in our study. With respect to PTSD, prior studies reported increased P1 amplitudes in soldiers with high PTSD symptoms when compared to soldiers with low PTSD symptoms (Zuj et al., 2017). However, this study did not use words and did not include an unexposed, healthy control group. Using neutral and traumatic words, Kounios et al. (1997) found diminished P1 activity in PTSD, regardless of emotional valence. On the other hand, a recent study comparing participants with a history of sexual abuse with healthy controls showed greater responses for neutral than negative emotional words in the control group but not for the traumatized group (Grégoire, Caparos, Leblanc, Brisson, & Blanchette, 2018). The EPN component was additionally examined because it has been reported in the context of early processing of pleasant and unpleasant stimuli and has been associated with initial stages of attention orientation (Schupp, Junghöfer, Weike, & Hamm, 2003). In the context of PTSD research, there are mixed results. Some studies reported reduced EPN in patients with PTSD for threatening emotional pictures (Adenauer et al., 2010) or faces (Felmingham et al., 2003). However, Elbert et al. (2011) reported a contrastive pattern between patients with PTSD and healthy controls using emotionally arousing pictures. While healthy controls showed largest EPN responses to positive pictures, patients with PTSD showed the most pronounced EPN amplitudes for aversive pictures. Moreover, prior studies with healthy participants could demonstrate the ability of affective words to modulate the EPN (Herbert et al., 2008; Kissler et al., 2007, 2009; Schacht & Sommer, 2009; Scott, O'Donnell, Leuthold, & Sereno, 2009).

2 | METHOD

The present study is part of a larger treatment study protocol (for details, see Rosner et al., 2014) and contains participants recruited at different German treatment facilities in Frankfurt, Berlin, and Ingolstadt, as well as participants for the healthy control group that were recruited from a school near Bielefeld. All participants were adolescents and young adults aged 14 to 21 years and had sufficient knowledge of the German language. Participants under the age of 18 were provided with written information about the study and received an informed consent document that had to be signed by their legal guardians. For the experimental group ($n = 40$), the main criterion for inclusion was suffering from PTSD as a primary diagnosis following CSA and/or CPA after the age of 3, according to the definition of the American Psychological Association (2013). Patients were diagnosed using the Structured Clinical Interview for DSM Disorders (SCID-I/SCID-II; First, Gibbon, & Spitzer, 1997; First, Spitzer, Gibbon, & Williams, 1995). In addition to this, a stable psychopharmacological medication was required, meaning either no or consistent psychopharmacological medication during the last 3 weeks. Other inclusion criteria included living in safe conditions and the reliability of the participant.

For the participants in the PTSD group, the following exclusion criteria were applied: acute suicidality within the last 6 months, life-threatening self-harming behavior within the last 6 months, substance-related or organic mental disorder, pervasive developmental disorder, acute or lifetime diagnosis of a psychotic disorder according to the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV-TR; American Psychiatric Association, 2000), acute or lifetime diagnosis of a bipolar disorder according to DSM-IV-TR, current diagnosis of substance dependence according to DSM-IV-TR (abstinence less than 6 months), mental retardation (IQ less or equal to 75), simultaneous psychological or psychiatric treatment. For the participants of the control group ($n = 38$), the following exclusion criteria were applied: any acute or lifetime diagnosis of an Axis 1 or Axis 2 psychological disorder according to DSM-IV-TR. In order to make sure no participant of the control group met the exclusion criteria, the SCID-I was conducted at the beginning of the experiment. For details regarding demographics and psychopathology, see Table 1. The study was approved by the Ethical Committee of the Department of Psychology of Bielefeld University.

TABLE 1 Subject characteristics and mean values on the assessments

	PTSD sample (*n* = 40)	Control group *n* = 38	*p*
Age, *M* (SD)	18.15 (2.21)	16.42 (1.09)	.44
Gender, % female (*n*)	85% (34)	60.5% (23)	<.05[a]**
Education (years), *M* (SD)	9.95 (1.31)	10.42 (.83)	.06
Culture Fair Intelligence Test, *M* (SD)	101.93 (16.24)		
Childhood trauma questionnaire, *M* (SD)	54.09 (19.02),	32.16 (8.21)	<.001**
Emotional abuse, *M* (SD)	12.65 (5.67)	6.92 (2.24)	<.001**
Emotional neglect, *M* (SD)	13.38 (6.55)	8.08 (3.15)	<.001**
Physical abuse, *M* (SD)	9.29 (4.92)	5.55 (1.31)	<.001**
Physical neglect, *M* (SD)	9.54 (4.73)	6.13 (1.44)	<.001**
Sexual abuse, *M* (SD)	9.09 (5.37)	5.47 (2.6)	<.001**
Beck depression inventory, *M* (SD)	25.10 (12.77)	6.11 (5.7)	<.001**
PTSD-RI			
Total score, *M* (SD)	39.53 (12.91)	7.61 (9.9)	<.001**
Intrusion, *M* (SD)	12.4 (4.64)	1.55 (3.11)	<.001**
Avoidance, *M* (SD)	14.95 (6.26)	2.76 (4.36)	<.001**
Arousal, *M* (SD)	12.18 (4.83)	3.29 (3.99)	<.001**
TSC-C			<.001**
Anxiety, *M* (SD)	14.65 (20.54)	3.37 (2.49)	
Depression, *M* (SD)	13.3 (13.58)	3.66 (3.29)	<.001**
Posttraumatic Stress, *M* (SD)	16.83 (17.07)	3.63 (3.11)	<.001**
Sexual Concerns, *M* (SD)	4.6 (4.47)	2.92 (3.59)	.07
Dissociation, *M* (SD)	12.65 (14.11)	4.34 (3.65)	<.001**
Anger, *M* (SD)	11.78 (20.91)	3.95 (3.71)	<.05[*]

[a]Chi-square-test.
*p ≤ .05; **p ≤ .001.

TABLE 2 Stimulus lexical characteristics

	Word group			
	Neutral	**Positive**	**Physically threatening**	**Socially threatening**
Valence	0.04 (0.48)[a]	1.40 (0.67)[b]	–1.17 (0.66)[b]	–1.25 (0.69)[c]
Arousal	–1.09 (0.92)[a]	–0.76 (1.12)[b]	0.31 (1.06)[c]	0.32 (1.12)[c]
Word length	6.72 (1.33)[a]	7.20 (1.93)[a]	7.44 (2.59)[a]	8.28 (2.73)[a]
Word frequency	11.60 (2.58)[a]	10.52 (1.87)[a]	12.84 (2.85)[a]	16.00 (3.41)[b]

Ratings for valence and arousal range from -1 (extremely negative valence/extremely low arousal) to 2 (extremely positive valence, extremely high arousal). Word length and frequency are based on written German and based on the CELEX database. SDs are displayed in parentheses. Different indices (a, b, c, d) represent results from post-hoc Scheffé-tests between word groups, lower case superscript alphabets indicate different indices with significant differences (all Ps < .05)

2.1 | Stimuli and procedure

The stimuli consisted of 100 German nouns from four different affective categories (neutral, positive, physically threatening, socially threatening). The stimulus set was originally created for and used in another study (Wabnitz, Martens, & Neuner, 2012) and could elicit differential processing as a function of affective valence. While socially threatening words were represented by swear words (e.g., *Hurensohn*,

i.e., *son of a bitch*), physically threatening words conveyed physical threat (e.g., *Qual*, i.e., *torment*), and positive words described different actions, places, or conditions that were associated with positive valence (e.g., *Ferien* or *Paradies*, i.e., *holidays* or *paradise*). Neutral words were less arousing and valent and depicted things or places (e.g., *Lesesaal* or *Lampe*, i.e., *reading room* or *lamp*). Wabnitz et al. (2012) obtained ratings from 55 university students in regard to valence and arousal for each word. For lexical characteristics (valence,

arousal, word length, word frequency), refer to Table 2; the complete (translated) stimulus set is provided as supporting information, Appendix S1.

Before the actual experiment, all participants completed several questionnaires: the Beck Depression Inventory (BDI-II; Kühner, Bürger, Keller, & Hautzinger, 2007), the Childhood Trauma Questionnaire (CTQ; Wingenfeld et al., 2010), the UCLA Posttraumatic Stress Disorder Reaction Index (PTSD-RI; Steinberg, Brymer, Decker, & Pynoos, 2004), and the Trauma Symptom Checklist for Children (TSC-C; Briere, 1996). The experiment consisted of six blocks, with each block consisting of a passive viewing paradigm of all 100 words, presented in a randomized order. Each stimulus was shown for 4,000 ms and was replaced by a fixation cross; the intertrial interval was 500 ms. In order to maintain attention to the stimuli, participants were asked to respond to a magenta dot that appeared in 15% of the trials for 67 ms by pressing the right arrow key of a standard keyboard. The stimuli were presented on a 15-in. computer monitor, approximately 60 cm in front of the participant's eyes, and were shown in white letters (Arial font, 36-point) on a black background.

2.2 | EEG recording and analyses

EEG was recorded from 32 BioSemi active electrodes (www.biosemi.com). Recorded sampling rate was 512 Hz. Electrodes were fitted into an elastic cap following the BioSemi position system. Two separate electrodes were used as ground electrodes, a common mode sense active electrode and a driven right leg passive electrode, which form a feedback loop that enables measurement of the average potential close to the reference in the A/D box (www.biosemi.com/faq/cms&drl.htm).

Preprocessing and statistical analyses were done using BESA (www.besa.de) and EMEGS (Peyk, De Cesarei, & Junghöfer, 2011). Offline, data were rereferenced to the average reference and then filtered with a forward 0.10 Hz high-pass (6 db/oct) and a zero-phase 30 Hz low-pass (24 db/oct) filter. Filtered data were segmented from 100 ms before stimulus onset until 1,000 ms after stimulus presentation. The 100 ms before stimulus onset were used for baseline correction. Eye movements were corrected using the automatic eye artifact correction method implemented in BESA (Ille, Berg, & Scherg, 2002). Additionally, trials exceeding a threshold of 120 μV were rejected. On average, 4.75% of all trials were rejected. There were no differences in retained trials between word categories, $F(2.52, 191.80) = 0.21$, $p = .862$, partial $\eta^2 = .003$, nor, importantly, was there an interaction between word categories and group, $F(2.52, 191.80) = 0.70$, $p = .529$, $\eta_p^2 = .009$.

2.3 | Statistical analyses

EEG scalp data were statistically analyzed with EMEGS. Two (Group: patients vs. healthy controls) × 4 (Valence: socially threatening, physically threatening, neutral, positive) repeated measures analyses of variance (ANOVAs) were set up to investigate potential main effects for group, emotion, and their interaction in time windows and electrode clusters of interest. Partial eta-squared (η_p^2) was estimated to describe effect sizes (Cohen, 1988). When Mauchly's test detected a violation of sphericity, degrees of freedom were corrected according to Greenhouse-Geisser. After visual inspection of the collapsed localizers, time windows were segmented from 130–160 ms for the P1 component, from 200–280 ms for the EPN component, from 300–400 ms for the P3 component, and from 400–650 ms and 650–900 ms for the LPP. For the P1, a parieto-occipital cluster of five electrodes (PO3, PO4, O1, Oz, O2) was selected. For the EPN, two symmetrical occipital sensor clusters, each consisting of three electrodes, were examined (left: P7, PO3, O1; right: P8, PO4, O2). Finally, P3 amplitudes were scored from a centro-parietal cluster of five electrodes (CP1, CP2, P3, Pz, P4). For early (400–650 ms) and late (650–900 ms) portions of the LPP, we used an anterior (F3, Fz, F4, FC1, FC2) and posterior (P3, Pz, P4, PO3, PO4) electrode cluster of five electrodes each, including position and time as a factor (e.g., see Kissler et al., 2009; Schindler, Wegrzyn, Steppacher, & Kissler, 2014; Solomon, DeCicco, & Dennis, 2012; Tempel et al., 2013).

3 | RESULTS

3.1 | ERP

3.1.1 | P3

For the P3 component, over the centro-parietal cluster, a significant effect of emotional valence was found, $F(3, 228) = 2.81$, $p = .040$, $\eta_p^2 = .036$. Here, positive words elicited a smaller P3 compared to physically threatening words ($p = .013$) and neutral words ($p = .024$). All other comparisons were not significant ($p > .096$). There was no significant group difference for the P3, $F(1, 76) = 2.36$, $p = .129$, $\eta_p^2 = .030$, and no interaction of group with emotional valence, $F(3, 228) = 0.13$, $p = .941$, $\eta_p^2 = .002$.

3.1.2 | LPP

In the early LPP time window (400–650 ms), the ANOVA revealed an interaction of emotional valence and group, $F(2.40, 182.10) = 3.46$, $p = .026$, $\eta_p^2 = .043$. While no main effect of emotional valence was found for healthy controls, $F(3, 111) = 1.40$, $p = .246$, $\eta_p^2 = .037$ (see Figure 1), PTSD patients showed a robust emotion effect, $F(2.19, 85.46) = 5.14$, $p = .002$, $\eta_p^2 = .116$. Within PTSD patients, socially threatening words elicited a larger LPP compared to physically threatening words ($p = .002$), neutral words ($p = .002$), and positive words ($p = .037$), while positive words did show a larger positivity compared to neutral words as well ($p = .014$).
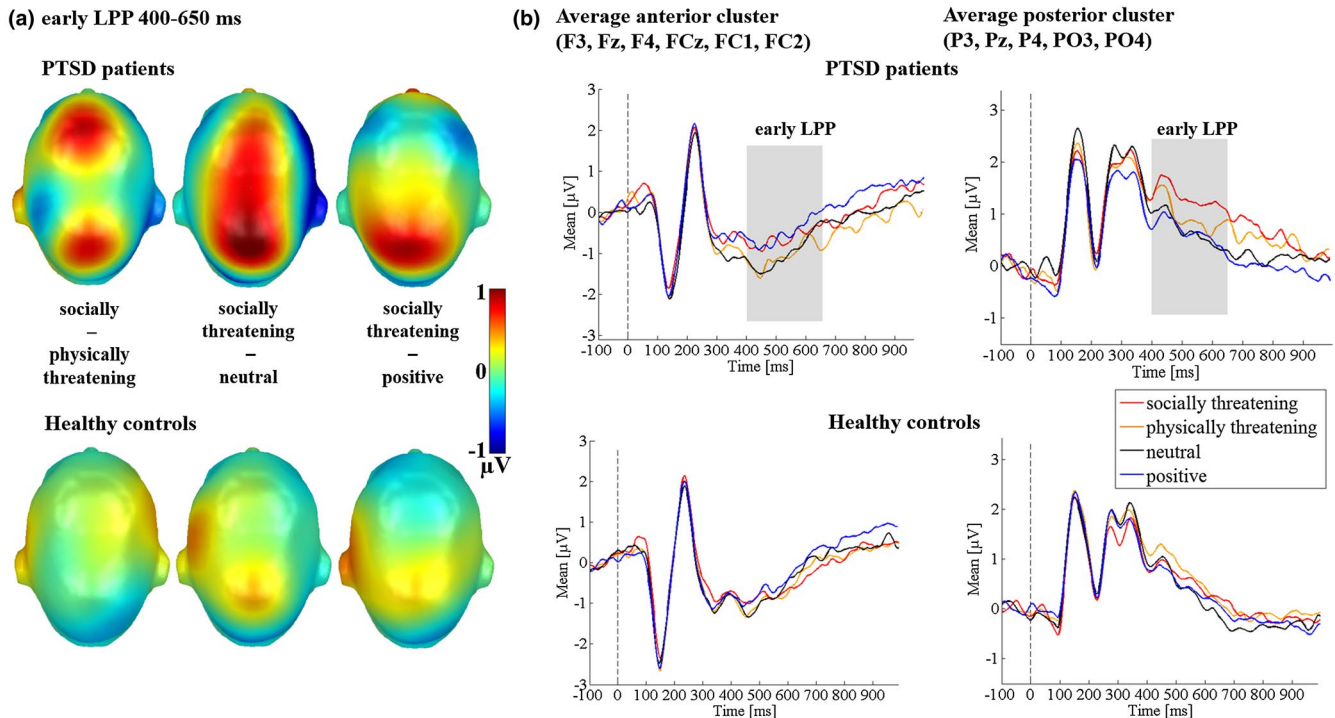
(a) early LPP 400-650 ms

PTSD patients

socially
–
physically
threatening

socially
threatening
–
neutral

socially
threatening
–
positive

Healthy controls

(b) Average anterior cluster (F3, Fz, F4, FCz, FC1, FC2)

Average posterior cluster (P3, Pz, P4, PO3, PO4)

FIGURE 1 Interactions of group and emotion in the early LPP. (a) Difference topographies. Within PTSD patients, socially threatening words elicit larger positivity over anterior and posterior regions. (b) Average microvolt values for the anterior and posterior cluster

Further, an interaction of emotional valence and region could be observed, $F(2.63, 200.11) = 3.40$, $p = .019$, $\eta_p^2 = .043$. In the anterior cluster, a main effect of emotion was detected, $F(2.52, 191.56) = 3.22$, $p = .031$, $\eta_p^2 = .041$, post hoc comparisons revealed that positive words elicited a larger positivity than physically threatening words ($p = .016$) and neutral words ($p = .003$). All other comparisons did not reach significance. For the main effect of emotional valence in the posterior cluster, $F(3, 231) = 4.93$, $p = .002$, $\eta_p^2 = .060$, post hoc comparisons showed that socially threatening and physically threatening words elicited a larger LPP compared to neutral ($p = .001$ and $p = .050$, respectively) and positive words ($p = .001$ and $p = .047$, respectively). All other comparisons were not significant ($ps > .477$).

The ANOVA also detected main effects of emotional valence, $F(2.40, 182.10) = 5.18$, $p = .004$, $\eta_p^2 = .064$, and region, $F(1, 76) = 31.65$, $p < .001$, $\eta_p^2 = .294$. Post hoc comparisons for the main effect of emotional valence showed that socially threatening words elicited a larger LPP compared to physically threatening words ($p = .014$) and compared to neutral words ($p = .001$) but not compared to positive words ($p = .084$). Further, positive words elicited a larger LPP compared to neutral words ($p = .003$) but not compared to physically threatening words ($p = .566$). Finally, physically threatening words did not differ from neutral words ($p = .168$). Post hoc comparisons for the main effect of region detected larger positivity over the posterior cluster ($p < .001$).

Regarding the main effect for group, the ANOVA did not reach significance, $F(1, 76) = 1.23$, $p = .271$, $\eta_p^2 = .016$. All other comparisons were not significant ($ps > .430$). All other possible interactions were not significant ($Fs < 0.48$, $ps > .694$).

In the late LPP time window (650–900 ms), the ANOVA revealed no main effects of emotional valence, $F(2.01, 153.03) = 2.17$, $p = .117$, $\eta_p^2 = .028$, region, $F(1, 76) = 0.08$, $p = .780$, $\eta_p^2 = .001$, or group, $F(1, 76) = 2.39$, $p = .127$, $\eta_p^2 = .030$. However, an interaction of emotion and region was found, $F(3, 228) = 5.05$, $p = .002$, $\eta_p^2 = .062$ (see Figure 2). Over anterior regions, a main effect of emotional valence, $F(2.65, 201.18) = 4.13$, $p = .010$, $\eta_p^2 = .052$, reached significance, with post hoc comparisons showing enhanced amplitudes for positive words compared to socially threatening ($p = .011$), physically threatening ($p = .004$), and neutral words ($p = .009$). All other comparisons did not reach significance ($ps > .302$). In contrast, post hoc comparisons for a posterior main effect of emotional valence, $F(3, 228) = 4.15$, $p = .007$, $\eta_p^2 = .052$, revealed a larger LPP for socially threatening words than for neutral words ($p = .005$) and positive words ($p = .005$). Further, physically threatening words showed more positivity compared to positive words ($p = .039$), while all other comparisons were not significant ($ps > .056$). Finally, all other interactions did not reach significance ($Fs < 2.83$, $ps > .097$).
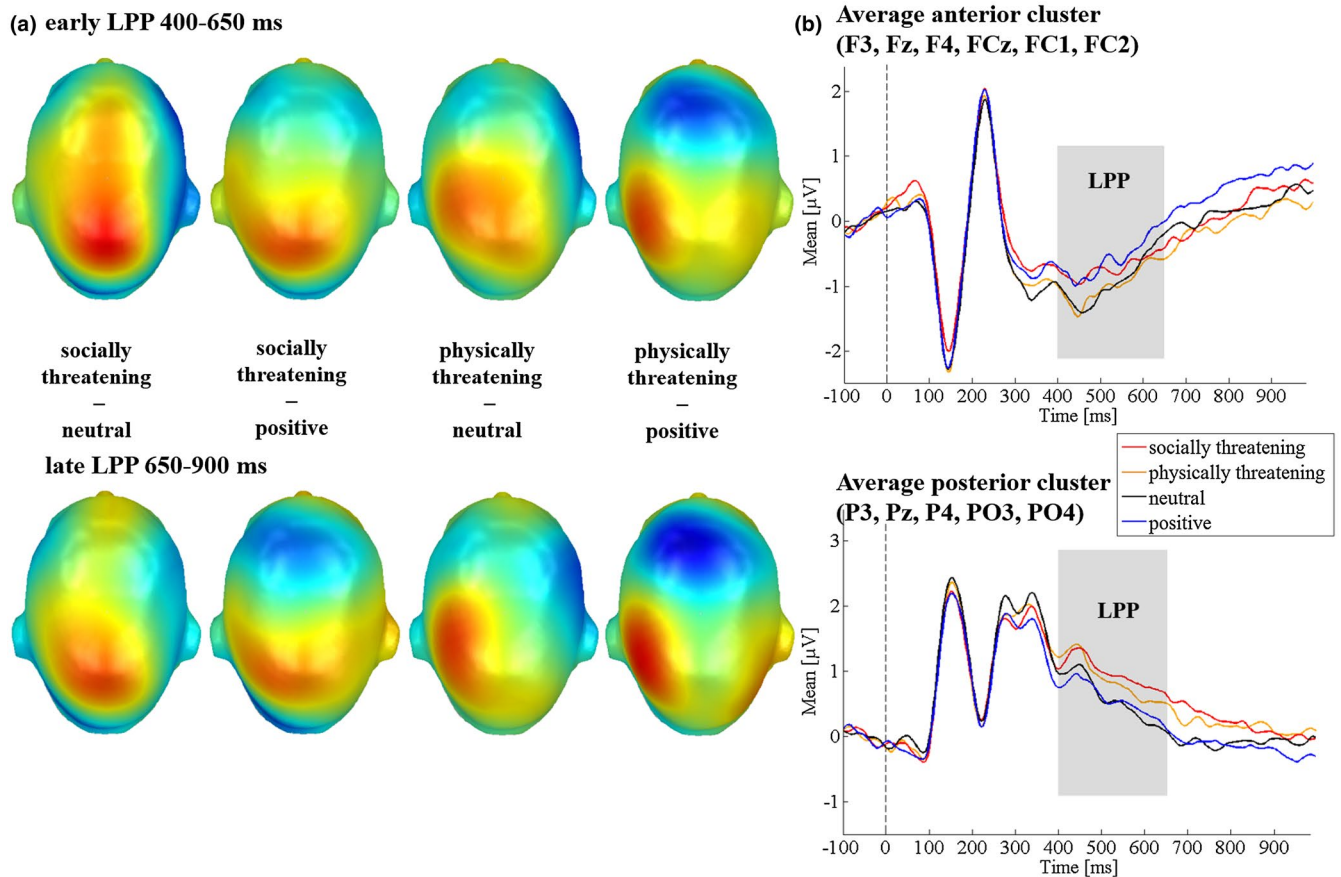
(a) early LPP 400-650 ms

socially threatening – neutral

socially threatening – positive

physically threatening – neutral

physically threatening – positive

late LPP 650-900 ms

(b) Average anterior cluster (F3, Fz, F4, FCz, FC1, FC2)

socially threatening
physically threatening
neutral
positive

Average posterior cluster (P3, Pz, P4, PO3, PO4)

FIGURE 2 Main effects of emotion in the LPP. (a) Difference topographies. Socially and physically threatening words elicit larger positivity over posterior regions; positive words elicit a larger positivity over anterior regions. (b) Average microvolt values for the anterior and posterior cluster

3.1.3 | P1

For the P1 component, no significant modulation of emotional valence was observed, $F(2.66, 202.44) = 0.69$, $p = .543$, $\eta_p^2 = .009$, and no interaction between group and emotional valence could be detected, $F(2.66, 202.44) = 0.89$, $p = .439$, $\eta_p^2 = .012$. Finally, there was no significant group difference on the P1, $F(1, 76) = 0.78$, $p = .380$, $\eta_p^2 = .010$.

3.1.4 | EPN

In the EPN time window, no main effect of emotional valence was found over occipital sensors, $F(2.66, 202.44) = 0.47$, $p = .685$, $\eta_p^2 = .006$, nor was there an interaction of group with emotional valence, $F(2.66, 202.44) = 0.67$, $p = .553$, $\eta_p^2 = .009$. There was a large effect of laterality, $F(1, 76) = 23.65$, $p < .001$, $\eta_p^2 = .237$, showing larger EPN amplitudes over the left hemisphere. There was no significant group difference for the EPN, $F(1, 76) < 0.01$, $p = .991$, $\eta_p^2 < .001$. Finally, no interactions between laterality and emotional valence, $F(2.59, 197.14) = 1.75$; $p = .166$, $\eta_p^2 = .022$, or of group,

laterality, and emotional valence were observed, $F(2.59, 197.14) = 0.23$; $p = .851$, $\eta_p^2 = .003$.

4 | DISCUSSION

The present study examined differential cortical responses to emotional (physically threatening, socially threatening, or positive) and neutral words and tried to assess different patterns between adolescent patients with PTSD and healthy adolescents. We discovered an interaction between groups and emotional valence in the analyzed early time window of the LPP, indicating a partially heightened LPP response for socially threatening stimuli in the PTSD group. Furthermore, distinct activation patterns for different emotional valences were observed between the anterior and posterior LPP electrode clusters. Also, we found valence-specific modulations of the P3, with positive words leading to relatively reduced amplitudes over both groups. With regard to early stages of information processing, no significant group differences were found at either the P1, EPN, or P3 stages.

In the early LPP time window, an interaction effect between emotional valence (socially threatening, physically

threatening, positive, neutral) and group (PTSD patients, healthy controls) was observed. Interestingly, while healthy controls showed no main effect for emotional valence, PTSD patients exhibited distinct augmented ERPs for socially threatening words in comparison to physically threatening, positive, and neutral words. The findings imply a distinct information processing pattern for individuals with PTSD for negative social cues. However, when interpreting the present results, it is important to consider some characteristics of the present PTSD sample. The recruited patients were all victims of childhood sexual and/or physical abuse. Therefore, they are likely to have experienced social humiliation in the course of their distress. While physically threatening words were represented by nouns such as *blood* or *bomb* in the current study, socially threatening words were represented by swear words. Following the hypothesis of an elaborated fear network after trauma, socially threatening words may have had the most relevance for the patients' fear networks when contrasted with all other categories used in this study. This relevance may have led to the strongest cognitive reactions when it comes to conscious processing. Interestingly, the current results are supported by a behavioral study by Dalgleish, Moradi, Taghavi, Neshat-Doost, and Yule (2001) who emphasized differences in the processing of socially threatening stimuli in adolescents with PTSD. In addition, analyses of the cardiac reactions in the present study indicated that responses to socially threatening words persisted longer in patients than in controls (Iffland et al., 2019). This may also be indicative of a more elaborated processing of socially negative words in PTSD patients after CSA/CPA. However, heart rate data to some extent contrasted the findings of cortical reactions. In comparison to the healthy control group, PTSD patients presented with a blunted cardiac response to physically threatening stimuli. While no differences in reaction to emotional words were present in the healthy control sample, cardiac reactions were significantly diminished in response to physically threatening words when compared to socially threatening, neutral, and positive words in the PTSD group (Iffland et al., 2019). The contradictory findings in relation to the reactions to physically threatening stimuli challenge the reliability of the paradigm used. Obviously, the stimuli and the chosen design were not able to provide clear evidence of neurophysiological differences between the samples. Rather, it seems to indicate valence-specific differences within the PTSD group. Here, further studies are warranted to integrate peripheral-physiological and cortical reactions to varying kinds of threatening stimuli and to examine specific associations to trauma history in different PTSD samples.

In addition to the described interaction between emotional valence and group, the LPP time windows revealed significant interactions between emotional valence and region (anterior and posterior electrode clusters). In the anterior electrode cluster, positive words led to augmented ERPs

in comparison to physically threatening and neutral (early LPP) and to socially threatening, physically threatening, and neutral words (late LPP). These findings are in line with Schindler et al. (2014) who also reported a larger positivity for positive words in comparison to neutral words. In the posterior electrode cluster, on the other hand, socially threatening and physically threatening words led to increased ERPs in comparison to neutral and/or positive words. These findings indicate valence-dependent variability between different LPP topographies, something that has also been found in the study by Schindler et al. (2014). In their study, the authors investigated the influence of context on the processing of emotional adjectives by varying the presumed source of the displayed words (evaluative adjectives chosen by a stranger versus randomly selected adjectives chosen by a computer). In this context, the human sender condition led to augmented ERPs for negative words, while there were no differences in the computer condition. The evaluative adjectives in the human sender condition are likely to be perceived as self-relevant information. Therefore, it could be speculated that, for posterior LPP topographies, the perceived self-relevance influences the way a stimulus is processed. On the other hand, anterior LPP topographies may be modulated solely by the emotional valence of the stimuli. This assumption is supported by a study from Klein et al. (2015). Here, interactions between the self-reference of emotionally valent context sentences indicated a variability of LPP modulations that was dependent on the perceived self-reference of a stimuli for posterior electrode clusters, while anterior electrode clusters revealed modulations by emotionally valent context information regardless of the perceived self-reference. Importantly, both studies (Klein et al., 2015; Schindler et al., 2014) only investigated healthy subjects. In the current study, while there was no significant triple interaction between region, emotion, and group, the results suggest that the differential processing of aversive words in both early and late LPP was mainly driven by the PTSD patients (see Figures 1 and 2). In this line of argument, it may be speculated that PTSD patients with a history of CSA and/or CPA automatically sensed an inherent self-relevance for the socially and physically threatening words, leading to augmented posterior processing of these words, while healthy controls did not generate any self-relevance and thereby did not exhibit significant posterior modulations. Consequently, early victimization may lead to implicit cognitive and emotional mechanisms (social information-processing model: Crick & Dodge, 1994; Rosen, Milich, & Harris, 2007), which may result in a tendency for self-related associations of negative information. However, further studies are necessary to further investigate this assumption.

While the P3 amplitudes for patients with PTSD were descriptively stronger than for the control group, this difference did not reach statistical significance. The lack of group effect is an interesting finding, as the P3 is thought to be one of the

most widely studied ERPs in psychophysiological PTSD research and is often postulated as a typical marker for psychiatric populations (Javanbakht et al., 2011). Surprisingly, most of the studies seem to have focused on general information-processing abnormalities (instead of emotional information-processing abnormalities) or characteristics of processing of trauma-related emotional material (Saar-Ashkenazy et al., 2015). In their meta-analysis, Johnson et al. (2013) reported a number of findings for different subtypes of the P3 component, using a variety of stimulus conditions (neutral, novelty, trauma-related). These findings indicated differences in information processing in PTSD, especially when using trauma-related stimuli. With respect to the present results, using standardized instead of specific trauma-related stimuli may have weakened the moderating impacts of PTSD on emotional information processing at the P3 stage.

Additionally, it is important to note that a majority of studies used either auditory or visual oddball paradigms. While these seem to be useful for their ability to elicit P3 amplitudes, the oddball design is mainly able to measure a specific kind of selective attention. Here, each stimulus is compared to a fixed mental representation of the targeted stimulus (J. D. Johnson et al., 2013). The paradigm used in our experiment was a passive reading paradigm and involved emotional words of different emotional valences. In our results, we did not find any specific differences for participants with PTSD at this stage. Instead, we found a valence effect indicating that positive stimuli elicited a weaker P3 compared to neutral and physically threatening stimuli in both groups. However, our findings contrast with prior findings. For example, in a study using the Stroop paradigm, Metzger and colleagues (1997) reported larger P3 amplitudes to both personal positive and traumatic words, compared to standard neutral words for both participants with PTSD and healthy controls. In a more recent study, which specifically investigated processing abnormalities for nontrauma-related, emotion-laden pictures in PTSD, Saar-Ashkenazy et al. (2015) identified augmented P3 amplitudes for negative pictures in healthy controls only. The authors subsequently suggested a tendency for negative overgeneralization in PTSD patients. Considering the wide range of differences between past studies (paradigm- and stimulus-wise), it seems necessary to keep these differences in mind when integrating our present findings.

Although the present study design did not specifically aim for the inspection of early stages of information processing, for the sake of completeness, our data were examined for additional group and emotion effects on P1 and EPN. In doing so, no specific modulation for patients with PTSD was found in the P1 range. An amplified P1 could have been indicative for hypervigilant information processing efforts in PTSD. However, in emotional word research, modulations of P1 are less frequently reported (Kissler, Assadollahi, & Herbert, 2006). Particularly, studies examining word processing

abnormalities in PTSD remain scarce (Javanbakht et al., 2011). In contrast, studies using other kinds of emotional stimuli, such as facial expressions, reported early emotion effects for PTSD (Zuj et al., 2017) or other anxiety disorders (Kolassa, Kolassa, Musial, & Miltner, 2007; Mueller et al., 2009; Mühlberger et al., 2009). Here, studies yielded mixed results, showing either enlarged (Kolassa et al., 2009; Mühlberger et al., 2009) or attenuated (Mueller et al., 2009) P1 amplitudes for emotional faces. In addition to the use of words as stimuli, the results of the present study regarding the P1 may also be influenced by sample characteristics. For instance, prior studies rarely examined samples of adolescents with PTSD and PTSD after CSA/CPA. Hence, it is difficult to draw any final conclusions, and further studies are needed addressing the particularities of early information processing in PTSD.

Similarly, no effect of emotional content was found for the EPN time range, contrasting with prior studies reporting either heightened (Elbert et al., 2011) or attenuated (Adenauer et al., 2010; Felmingham et al., 2003) activation for threatening stimuli. Again, the type of stimuli and characteristics of the PTSD sample used in the present study may account for this. Additionally, it may be assumed that the lack of emotion or group effect was due to the rather slow presentation speed (4,000 ms). The long presentation time could have resulted in less demanding attentional orientation requirements, which might have contributed to smaller EPN modulations. Studies reporting strong emotion-related EPN modulations typically presented words for 300–600 ms (Kissler & Herbert, 2013; Kissler et al., 2007; Schindler & Kissler, 2016). In line with this, prior studies using the same paradigm did not find any EPN modulation in healthy participants (Wabnitz et al., 2012; Wabnitz, Martens, & Neuner, 2015). However, there has been a valence effect with socially threatening words when compared with neutral words leading to stronger EPN amplitudes in patients with social anxiety disorder (Wabnitz et al., 2015). Lastly, there was a large effect of laterality with larger EPN amplitudes occurring over the left hemisphere. These findings are in line with studies that indicated left-hemispheric activation as a sign of semantic processing of words (Kissler & Herbert, 2013; Kissler et al., 2007).

Moreover, the present study has several additional limitations. Our results may have been affected by differences in the reference of the word categories. While swear words (e.g., *asshole*) are normally used to directly address the recipient, words included in the other emotional categories (e.g., *blood*, *paradise*, *package*) are not. As other studies have been able to demonstrate the enhancing impact of self-reference on both the early and later stages of stimulus processing (Klein et al., 2015), future studies should control for this. For example, emotional words could be presented in a sentence structure varying in terms of self-reference. Moreover, there might have been differences

in word frequency in the present study. All words were equated for word length and frequency except for socially negative words (swear words), which were only equated for length. Word frequency has been observed to modulate the P3 component (Scott et al., 2009), where more-frequent words were found to elicit larger P3 amplitudes. However, in previous studies with the same paradigm, no impact of word frequency on ERP effects has been reported (Wabnitz et al., 2012, 2015). Additionally, socially threatening words did not have a differential effect at P3 stage. Another limitation may arise from the study design. As mentioned in the Methods section, a magenta dot randomly appeared in 15% of all trials. The participants were instructed to react to this dot with the idea to induce sustained attention to the center of the screen while passively reading the affective words. Although this may have worked in terms of heightened general attention, it could also have shifted the attentional focus to the magenta dots and thereby have influenced the results in terms of weakening the potential of the emotional ERP modulations. While our study was able to show valence-specific differences between groups in later processing steps, this could explain the lack of stimulus-driven valence effects in earlier time windows (e.g., EPN). Furthermore, an additional limitation may arise from the diverse findings within the LPP time range. The results of the early LPP indicate a PTSD-specific augmentation for socially threatening words, while similarly enhanced amplitudes by social threat were shown for the later LPP regardless of group. Even though the waveforms display this effect to be mainly driven by the patient group, this limitation may still narrow the informative value of the early LPP results.

Our study is in line with other research, suggesting a differential attentional bias for individuals with PTSD, which may be the result of an altered fear network. Our findings of modulated emotional information processing in the examined adolescent patient sample were limited to the early LPP. Still, the findings provide implications for an attentional bias in PTSD in adolescents after CSA/CPA. Interestingly, those with PTSD exhibited augmented early LPP amplitudes for socially threatening words in comparison to physically threatening, positive, and neutral words, while the healthy control group revealed no differential emotional modulations. Our study is, to our knowledge, among the first to expand this field of research to adolescent patients with PTSD who were victims of CSA and/or CPA. The present findings may help to further break down the basic principles of altered information processing in PTSD and to find characteristic features specific to adolescents with PTSD. Additionally, the findings will hopefully encourage the further examination of possible abnormalities for PTSD in adolescence and, based on present and future findings, advance existing therapeutic approaches.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1