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Cardiac reactions to emotional words in adolescents and young adults with PTSD after child abuse

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Abstract

Post-traumatic stress disorder (PTSD) is associated with alterations in cardiac reactivity to threat cues. Meta-analyses have summarized that adults with PTSD have increased heart rates in response to trauma-related stimuli. However, the opposite effect (i.e., cardiac hyporeactivity) has recently been reported in subgroups of PTSD patients. In children and adolescents with PTSD, reports of cardiac alterations are rare and ambiguous. So far, most studies in adolescents and young adults are restricted to victims of accidents, even though PTSD is highly prevalent in victims of child maltreatment. The present study aimed at investigating cardiac reactions in adolescents and young adults with PTSD after child abuse. Cardiac responses to standardized emotional words were studied in 39 adolescent and young adult PTSD patients after childhood sexual and/or physical abuse as compared to 39 healthy control subjects (age range: 15–20 years). The experimental paradigm consisted of a passive reading task with neutral, positive, physically threatening, and socially threatening (swear) words. Results showed that cardiac reactions to negative stimuli, particularly physically threatening stimuli, were less pronounced in PTSD patients than in controls. Moreover, cardiac reactions in response to socially threatening words were less variable in the PTSD group. No differences between and within groups were present in reaction to neutral or positive stimuli. Findings suggest that a physiologically blunted subtype of PTSD may already manifest during adolescence and young adulthood. Moreover, the results of the present study emphasize the relevance of individual trauma history for physiological reactions.

KEYWORDS
childhood abuse, electrocardiography, heart rate, passive reading paradigm, posttraumatic stress disorder, psychophysiology, trauma

1 | INTRODUCTION

Psychophysiological alterations are a core diagnostic feature of post-traumatic stress disorder (PTSD; Langeland & Olff, 2008). With respect to cardiac changes in PTSD patients, meta-analyses have reported that adults with PTSD have a higher heart rate at rest when compared to control groups with or without a history of trauma exposure. In addition to a higher baseline heart rate, PTSD patients show larger cardiac responses to startling sounds and to idiosyncratic trauma reminders (Buckley & Kaloupek, 2001; Pole, 2007). Likewise, PTSD patients react more strongly to standardized trauma cues than controls with or without a history of trauma exposure (Pole, 2007). Ehlers et al. (2010) demonstrated that trauma survivors with PTSD exhibit differential heart rate responses to standardized trauma-related pictures as early as 1 month after the trauma. Moreover, the increased cardiac reactivity of PTSD patients is not restricted to trauma reminders but generalizes to nontrauma-related emotional cues such as standardized affective pictures (Adenauer, Catani, Keil, Aichinger, & Neuner, 2010). Additionally, the importance of the relationship between heart rate responses and PTSD has been emphasized by findings that heart rate levels early after trauma exposure prospectively predict PTSD (Bryant, Harvey, Guthrie, & Moulds, 2000; Shalev et al., 1998). Here, an elevated heart rate was indicative of increased PTSD symptoms. To sum up, besides higher baseline heart rates and its predictive value for PTSD symptoms, enhanced heart rate reactivity in PTSD patients has been shown to include both greater heart rate deceleration in response to threatening stimuli as well as greater subsequent heart rate acceleration when threat was perceived as imminent (Adenauer et al., 2010; Cuthbert et al., 2003; McTeague et al., 2010). Here, depending on the nature of tasks and stimuli used, prior studies were able to detect either deceleration or acceleration of heart rates (Pole, 2007).

However, several studies in recent years have reported conflicting findings. In some studies, individuals with PTSD showed no differences in cardiac reactivity relative to controls or even responses that declined from baseline (Cuthbert et al., 2003; D'Andrea, Pole, DePierro, Freed, & Wallace, 2013; Limberg, Barnow, Freyberger, & Hamm, 2011; McTeague & Lang, 2012). This pattern of cardiac hyporeactivity has been linked to the presence of dissociation (Lanius, Brand, Vermetten, Frewen, & Spiegel, 2012), multiple traumatic events (Cuthbert et al., 2003; McTeague et al., 2010), extreme PTSD symptoms and trauma exposure (D'Andrea et al., 2013), as well as early developmental occurrence of traumatization (Quevedo, Smith, Donzella, Schunk, & Gunnar, 2010). Consistent with the latter physiological findings, clinical studies (Van der Kolk, Roth, Pelcovitz, Sunday, & Spinazzola, 2005; Zucker, Spinazzola, Blaustein, & van der Kolk, 2006) identified a dissociative, physiologically blunted subtype of PTSD (D'Andrea et al., 2013) that had recently been recognized as part of the DSM-5 PTSD diagnosis (American Psychiatric Association, 2013).

In children and adolescents with PTSD, studies on psychophysiological, particularly cardiac, alterations are rare and ambiguous and generally do not replicate findings from adult PTSD (Kirsch, Wilhelm, & Goldbeck, 2011). While an elevated heart rate immediately post-trauma seems to predict PTSD, no abnormalities in heart rate during rest or tasks with nontrauma-related stressors have been found among children and adolescents with PTSD (Jones-Alexander, Blanchard, & Hickling, 2005; MacMillan et al., 2009; Saltzman, Holden, & Holahan, 2005). On the other hand, Saltzman et al. (2005) reported significantly higher heart rate in trauma-exposed children compared to nonexposed controls at baseline and immediately after an interview about traumatic events. However, elevation of heart rate was independent from PTSD status as it could not differentiate between traumatized subjects with and without PTSD (Saltzman et al., 2005; Scheeringa, Zeanah, Myers, & Putnam, 2004). Likewise, no differences in heart rate reactions to idiosyncratic trauma scripts were found between children and adolescents with PTSD and a traumatized control group (Kirsch, Wilhelm, & Goldbeck, 2015).

Taken together, the present literature suggests that elevated heart rate in reaction to trauma and nontrauma-related threatening cues is specific to adults with PTSD, while heart rate reactivity is associated with trauma history but not PTSD among children and adolescents (Buckley & Kaloupek, 2001; Kirsch et al., 2011, 2015). However, current studies with traumatized children and adolescents have not considered that the characteristics of the traumatic event can be crucial for the development and the severity of PTSD symptoms as well as for the direction of psychophysiological alterations (D'Andrea et al., 2013; Kirsch et al., 2015; Langeland & Olff, 2008). In the PTSD literature on children and adolescents, most studies investigated traumatized subjects after single trauma exposure such as motor vehicle accidents. Given the high prevalence rates of childhood sexual abuse (CSA) and childhood physical abuse (CPA) and the related very high risk of developing PTSD after CSA/CPA, there is a need to extend the focus of research to younger, adolescent populations suffering from CSA/CPA-related PTSD (Rosner, König, Neuner, Schmidt, & Steil, 2014). CSA has been linked with heightened risks for several mental diseases (Cutajar et al., 2010; Stirling & Amaya-Jackson, 2008). There is a particularly high probability for the development of PTSD after CSA, with studies reporting prevalence rates ranging from 37% to 52% (McLeer, Deblinger, Henry, & Orvaschel, 1992; McLeer et al., 1998; Norman et al., 2012). Moreover, a recent study examined the influence of trauma type on the risk of developing a subsequent PTSD diagnosis. The authors reported prevalence rates of 53.3% (with an additional 33.3% developing a partial PTSD syndrome) for CSA, emphasizing the high risk of developing PTSD after CSA (Glaesmer, Matern, Rief, Kuwert, & Braehler, 2015). Similarly, in their meta-analysis, Norman et al. (2012) demonstrated significant associations between CPA and PTSD.

Regarding these trauma types, CPA and CSA are interpersonal traumas that include the violation of the victim's personal and physical integrity. These particular traumas also carry social stigma with them. Consequently, it is possible that not only stimuli indicating physical threat but also signs of interpersonal or social threat are suitable to evoke trauma-related physiological reactions. This is in line with the increasing evidence for the role of emotional abuse and neglect in the etiology of PTSD (Spertus, Yehuda, Wong, Halligan, & Seremetis, 2003; Teicher, Samson, Polcari, & McGreenery, 2006) as well as findings about altered information processing in the wake of emotional abuse (Ito et al., 1993; Ito, Teicher, Glod, & Ackerman, 1998). In recent studies, images or faces were mainly used as threat-related or threat-provoking stimuli to activate physiological reaction patterns. However, the studies generally did not distinguish between physically and socially threatening stimuli. With respect to recent studies reporting that emotional words are as equally suitable as images or faces when evoking emotional processes and reactions (Herbert, Junghofer, & Kissler, 2008; Kissler, Herbert, Peyk, & Junghofer, 2007; Schacht & Sommer, 2009a, 2009b), the current study sought to distinguish between physically and socially threatening stimuli by using emotional words. In the current study, the latter will be represented by swear words. Swear words express strong emotion and were shown to be related to social threatening (Chun, Choi, Cho, Lee, & Kim, 2015; Wabnitz, Martens, & Neuner, 2012). Recently, it was reported that swear words elicited a neural response in the same regions that were previously shown to be related to the pain of social rejection resulting from being excluded from an important social relationship (Chun et al., 2015; Eisenberger & Lieberman, 2004). Hence, swearing appears to be sufficient to verbally hurt another person and to serve as an alarm signal of potential threat (Jay, 2000; Vingerhoets, Bylsma, & de Vlam, 2013). Accordingly, both verbal and physical aggression often go along with swearing (Rassin & Muris, 2005). In addition, Jay (2009) stated that sexual intimidation, discrimination, and verbal abuse are often accompanied with swear words (Vingerhoets et al., 2013). This may be of interest especially for subjects with PTSD after CSA/CPA, because socially threatening swear words may be associated with peri-traumatic experiences and therefore suitable to evoke differential reactions in the PTSD group.

The aim of the current study was to contribute to a better understanding of cardiac reactions in adolescents and young adults with a history of CSA and/or CPA who developed PTSD. The PTSD group was compared to healthy adolescents and young adults matched for age, gender, and educational level. We sought to examine whether there are considerable differences in the cardiac reaction to emotional words between adolescent and young adult patients with PTSD and healthy control subjects. With respect to former results, one may postulate that PTSD patients should show greater heart rate acceleration to negative stimuli than to neutral or positive stimuli in comparison to healthy control subjects (Adenauer et al., 2010; Buckley & Kaloupek, 2001; Pole, 2007). However, findings of cardiac hyporeactivity in PTSD patients with multiple incidences of traumatization (Cuthbert et al., 2003; McTeague et al., 2010), as well as early developmental occurrence of traumatization (Quevedo et al., 2010), suggest that PTSD after CSA and/or CPA may be associated with a blunted cardiac response to negative stimuli but not neutral and positive stimuli. Hence, we hypothesized that adolescents and young adults with PTSD after CSA/CPA would show blunted cardiac responses to threatening standardized words when compared to healthy control subjects. Based on findings that PTSD is characterized by a generalization of learned fear responses to stimuli that resemble the original traumatic situation (Ehlers et al., 2010; Foa, Steketee, & Rothbaum, 1989; Keane, Zimering, & Caddell, 1985), we expected similar patterns of heart rate responses to both physically and socially threatening standardized, nontrauma-related emotional words in adolescents and young adults with PTSD after CSA and/or CPA.

2 | METHOD

2.1 | Participants

The present study is part of a larger treatment study protocol (for details, see Rosner et al., 2014) and assessed participants recruited from three German university outpatient clinics in Frankfurt, Berlin, and Ingolstadt. Participants of the healthy control group were recruited from a comprehensive school near Bielefeld, Germany. All participants were adolescents and young adults between the ages of 15 and 20 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, which had to be signed by their legal guardian. For the experimental group (n = 39), the main criterion for inclusion was 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 German version of the Clinician Administered PTSD Scale for Children and Adolescents (CAPS-CA; Steil & Füchsel, 2006) and the German version of the Structured Clinical Interview for DSM Disorders (SCID; Wittchen, Zaudig, & Fydrich, 1997). In addition to this, a stable psychopharmacological medication history was required, meaning either no or a constant psychopharmacological medication during the previous 3 weeks. Other inclusion criteria were living in stable conditions (no ongoing victimization, not homeless) and sufficient knowledge of German language (clearly able to understand the information and instructions). For the participants in the PTSD group, exclusion criteria included acute suicidality within the previous 6 months, life-threatening self-harming behavior within the last 6 months, the presence of a substance-related or organic mental disorder, pervasive developmental disorder, acute or lifetime diagnosis of a psychotic disorder, acute or lifetime diagnosis of a bipolar disorder, current diagnosis of substance dependence (abstinence less than 6 months) according to the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV-TR; American Psychiatric Association, 2000), mental retardation (IQ less than or equal to 75), and simultaneous psychological or psychiatric treatment. For the participants of the healthy control group ($n = 39$), exclusion criteria included any acute or lifetime diagnosis of an Axis I or Axis II mental disorder according to DSM-IV-TR. In order to make sure no participant of the control group met the exclusion criteria, a structured clinical interview was conducted at the beginning of the experiment (SCID; Wittchen et al., 1997). Details regarding demographics and psychopathology are presented in Table 1. The study was approved by the Ethics Committee of Bielefeld University, the local independent review boards of Catholic University Eichstätt-Ingolstadt, Goethe University Frankfurt, and Freie Universitaet Berlin.

2.2 | Instruments

In the PTSD sample, the presence and severity of PTSD was determined by the CAPS-CA (Nader, Kriegler, Blake, & Pynoos, 1994; German version: Steil & Füchsel, 2006). This structured clinical interview was developed to assess the frequency and intensity of PTSD symptoms on a scale ranging from 0 (*never*) to 4 (*daily or almost daily*) and from 0 (*none*) to 4 (*extreme*), respectively. Symptom severity was determined by the sum of frequency and intensity ratings (range, 0–148). Comorbidity was measured with the German version of the Structured Clinical Interview for DSM Disorders (SCID; First, Spitzer, Gibbon, Williams, & Benjamin, 1994; First, Spitzer, Gibbon, & Williams, 1997; Wittchen et al., 1997). In the healthy control sample, only the SCID was administered. The interviews were conducted by masters-level clinical psychologists who were trained in the application of the CAPS-CA and SCID. In addition, the University of California Los Angeles PTSD Reaction Index (UPID; Steinberg, Brymer, Decker, & Pynoos, 2004; German version: Ruf, Schauer, & Elbert, 2010) provided a self-rating of PTSD symptoms. Moreover, the German version of the Trauma Symptom Checklist for Children (TSCC; Briere, 1996; Matulis et al., 2015) was used to assess trauma-related symptoms. The German version of the Childhood Trauma Questionnaire (CTQ; Wingenfeld et al., 2010) was used to assess different types of childhood maltreatment (sexual abuse, emotional neglect, emotional abuse, physical neglect, physical abuse). The items are rated from 1 (*never true*) to 5 (*very often true*) with a possible range of subscale scores from 5 to 25. The psychometric properties of the German version are similar to the original version, and it has been shown to be a reliable and valid screen for childhood maltreatment. Moreover, we applied cutoff scores established by Walker et al. (1999) for the CTQ subscales to decide whether the dichotomous criteria of different types of child abuse were fulfilled. Maltreatment is assumed when threshold scores for emotional abuse (10), emotional neglect (15), physical abuse (8), physical neglect (8), and sexual abuse (8) are met. Symptoms of depression were measured using the German version of the Beck Depression Inventory (BDI-II; Hautzinger, Keller, & Kühner, 2006). The self-report measure consists of 21 items assessing symptoms of depression. Higher scores indicate more severe depressive symptoms. The BDI-II has shown good psychometric properties in clinical and nonclinical samples (Kühner, Bürger, Keller, & Hautzinger, 2007). In the PTSD sample, the Culture Fair Intelligence Test (CFT-20-R; Weiß, 2006) was used to assess participants' intelligence quotient and to rule out mental retardation. On four subscales, the CFT-20-R measures basic or fluid intelligence with a minimum of cultural and educational bias. When participants were not able to complete the CFT-20-R properly (e.g., due to disorder-related concentration problems), school certificates were used to ensure that patients met the cognitive requirements to be included in the study.

2.3 | Procedure

Prior to the laboratory session, participants were informed about study conditions and asked to give informed consent. Afterward, a structured clinical interview served as screening for the inclusion and exclusion criteria of the study. If participants matched the requirements, they were asked to fill in an assessment battery including a sociodemographic questionnaire as well as the instruments described above. At the beginning of the laboratory assessment, sensors for peripheral physiological measurements were applied.

In order to assess participants' cardiac reactions to emotional words, a passive reading paradigm was used in which 100 German nouns from four different affective categories (neutral, positive, physically threatening, socially threatening) were presented to the participants on a display monitor. The stimulus set had been previously used (Wabnitz et al., 2012) and elicited differential processing as a function of affective valence. While socially threatening words were

TABLE 1 Participants' characteristics and mean values on the assessments

	Adolescent and young adult PTSD patients ($n = 39$)	Healthy control participants ($n = 39$)	p
Age, *M* (*SD*, range)	16.77 (1.37, 15–20)	16.49 (1.23, 15–20)	*ns*
Gender, % female (*n*)	79.5 (31)	71.1 (27)	*ns*[a]
Participants' educational level (years of education), *M* (*SD*)	10.15 (1.22)	10.36 (.84)	*ns*
School education of participants' mothers, % without any certificate (*n*)	5.6 (2)[b]	2.9 (1)[b]	*ns*[a]
Vocational education of participants' mothers, % without any (*n*)	19.4 (7)[b]	26.5 (9)[b]	*ns*[a]
Occupational level of participants' mothers, % unemployed (*n*)	16.2 (6)[b]	5.3 (2)[b]	.048[a]
School education of participants' fathers, % without any certificate (*n*)	6.5 (2)[b]	0.0 (0)[b]	*ns*[a]
Vocational education of participants' fathers, % without any (*n*)	0.0 (0)[b]	17.6 (6)[b]	*ns*[a]
Occupational level of participants' fathers, % unemployed (*n*)	12.5 (4)[b]	5.7 (2)[b]	*ns*[a]
Citizenship, % German (*n*)	92.3 (36)	100.0 (39)	*ns*[a]
Migration background, % yes (*n*)	25.6 (10)	38.5 (15)	*ns*[a]
Native language, % German (*n*)	89.7 (35)	76.9 (30)	*ns*[a]
Current residential situation, % living with family members (*n*)	69.2 (27)	100.0 (39)	.003[a]
Intelligence quotient (CFT-20-R), *M* (*SD*, range)	104.58 (16.44, 80–140)[b]		
Beck Depression Inventory, *M* (*SD*)	26.74 (13.45)	6.79 (5.98)	<.001
PTSD symptom load (CAPS-CA), *M* (*SD*)	62.85 (23.95)		
UCLA PTSD Reaction Index, *M* (*SD*)	40.97 (13.08)	13.58 (10.19)	<.001
Intrusion, *M* (*SD*)	13.00 (5.02)	2.56 (3.62)	<.001
Avoidance, *M* (*SD*)	15.56 (6.42)	5.08 (4.96)	<.001
Arousal, *M* (*SD*)	12.41 (4.12)	5.84 (4.01)	<.001
Trauma Symptom Checklist for Children			
Anxiety, *M* (*SD*)	10.61 (5.18)	3.89 (2.60)	<.001
Depression, *M* (*SD*)	11.97 (6.26)	4.11 (3.26)	<.001
Posttraumatic stress, *M* (*SD*)	15.36 (6.19)	3.95 (3.17)	<.001
Sexual concerns, *M* (*SD*)	4.79 (4.11)	2.82 (3.50)	.026
Dissociation, *M* (*SD*)	11.03 (6.84)	5.00 (3.73)	<.001
Anger, *M* (*SD*)	7.15 (4.62)	4.45 (3.59)	.005
Childhood Trauma Questionnaire, *M* (*SD*)	56.97 (20.07)	33.08 (8.68)	<.001
Emotional abuse, *M* (*SD*)	13.70 (5.75)	7.36 (2.64)	<.001
Emotional neglect, *M* (*SD*)	14.42 (6.44)	8.33 (3.27)	<.001
Physical abuse, *M* (*SD*)	9.88 (5.34)	5.59 (1.31)	<.001
Physical neglect, *M* (*SD*)	9.79 (4.95)	6.33 (1.61)	<.001
Sexual abuse, *M* (*SD*)	9.50 (5.49)	5.46 (2.56)	<.001

Note: $N = 78$.
[a]Chi-squared test.
[b]Smaller sample size due to missing values.

represented by swear words (e.g., "Missgeburt," i.e., *freak*), physically threatening words conveyed physical threat (e.g., "Bombe," i.e., *bomb*) and positive words described different actions, places, or conditions that were connected with a positive valence (e.g., "Ferien" or "Paradies," i.e., *holidays* or *paradise*). Neutral words 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. Neutral words were less arousing and valent. Socially and physically threatening words did not differ with respect to arousal and valence. Across valence categories, words were equated for word length and frequency, except for socially threatening words. The latter were less frequent based on the CELEX database for written German. Furthermore, all words were rated for perceived threat for physical and social integrity (Wabnitz et al., 2012).

The experiment consisted of six blocks. Within each block, all 100 words were presented in a randomized order. Each stimulus was shown for 4,000 ms and was replaced by a fixation cross that was present for 500 ms. The intertrial interval (ITI) 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 on 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. Throughout the experiment, cardiac reactions were measured. After completion of the task and sensor removal, participants were debriefed thoroughly.

2.4 | Peripheral physiological recording

Peripheral psychophysiological data were recorded with the ActiveTwo BioSemi system (BioSemi, Amsterdam, The Netherlands; www.biosemi.com). As per BioSemi's design, the ground electrode was formed by the common mode sense (CMS) active electrode and the driven right leg (DRL) passive electrode. All bioelectric signals were digitized on a laboratory microcomputer using ActiView software (BioSemi) and monitored online for data quality. Data were recorded with a sampling rate of 512 Hz. Electrocardiography (ECG) was recorded from Ag/AgCl sensors placed at the initial point of the sternum and at the distal end of the left costal arch.

Offline data inspection and manual artifact rejection for ECG was done in ANSLAB 2.6, a customized software suite for psychophysiological recordings (Blechert, Peyk, Liedlgruber, & Wilhelm, 2016). R waves in the ECG data were identified automatically. Additionally, data were visually inspected for artifacts and edited accordingly, resulting in manual replacements of artifactual data points, editing of nonrecognized R waves, and exclusion of sections with high proportions of artifacts. The ECG signal was converted to the instantaneous interbeat interval (IBI) indicating the time in milliseconds between successive R waves of the electrocardiogram. Cardiac responses were defined as averages across the 4,000-ms word presentation relative to a 500-ms baseline before the onset of the words. Hereafter, positive values represent increasing IBIs (deceleration of cardiac responses), while negative values represent a decrease of the IBI (acceleration of the cardiac responses). These response patterns were analyzed in 500-ms segments. In the statistical analyses, two time segments were averaged in each case, so that the analyses included four segments of 1,000-ms each. In further analyses, mean heart rate changes of all eight 500-ms segments were used.

2.5 | Data reduction and statistical analyses

All statistical analyses were carried out using the Statistical Package for the Social Sciences SPSS 25. For analyses of the cardiac reactions to the emotional words, a 2 (Group: PTSD patients vs. healthy controls) × 4 (Valence: neutral, positive, physically threatening, socially threatening) × 4 (Time: four 1,000-ms segments spanning image presentation) ANOVA with repeated measures on time and valence were conducted using the instantaneous IBI as dependent variable. When necessary, additional post hoc ANOVAs as well as *t* tests were conducted separately for different valences and PTSD patients versus healthy controls. When Mauchly's test indicated violation of the sphericity assumption, Greenhouse-Geisser corrections were applied, and original degrees of freedom together with Greenhouse-Geisser ε are reported. All ANOVAs were also carried out after exclusion of healthy controls that met threshold levels for physical abuse and sexual abuse ($n = 2$). As the pattern of results did not change, results of the total sample are reported. Furthermore, exploratory analyses using Pearson correlations were conducted to examine the associations of the psychopathological measurements and trauma history with physiological reactions to physically and socially threatening words in the sample of PTSD patients. For this purpose, contrast scores were computed by subtracting mean IBI changes across the stimulus presentation interval of 4,000 ms in reaction to neutral words from mean heart rate changes in reaction to physically as well as socially threatening words. Because correlation analyses were explorative and we aimed to detect potential associations instead of testing specific hypotheses, the less conservative Benjamini-Hochberg adjustment of significance levels was applied to control for multiple testing.

3 | RESULTS

The sample consisted of 78 participants (58 female, 74.4%), of which 39 individuals (50.0%) were diagnosed with PTSD and 39 individuals (50.0%) served as healthy controls. The average age was 16.63 years ($SD = 1.30$). As reported in Table 1, 89.9% of the PTSD patients and 76.9% of the healthy controls indicated German as their native language. Non-native speakers indicated that they had 4–17 years of experience with the German language (PTSD patients: 4–15 years; healthy controls: 6–17 years). Participants of the PTSD sample indicated that they lived in the following settings: 69.2% lived with their families (either with one parent, both parents, or in a patchwork setting), 5.1% in assisted living, 7.7% lived alone, 5.1% lived in an institutional care setting, and 12.8% lived in some other kind of setting or did not answer this question. The participants of the healthy control group all indicated that they lived with their families.

Of the PTSD sample, eight individuals indicated that they were currently receiving a psychopharmacological treatment. Of these, five individuals indicated use of antidepressants and three indicated use of a psychopharmacological medication but were not able to specify which kind. No further use of prescriptive medication except oral contraceptives was present in the PTSD sample. In the healthy control sample, no current use of prescriptive medication except oral contraceptives was indicated.

In PTSD patients, we found 89.7% meeting Walker et al.'s (1999) threshold severity criteria for at least one type of childhood abuse or neglect, as measured by the CTQ subscales. Threshold levels were met for emotional abuse for 61.5%, emotional neglect for 46.2%, physical abuse for 48.7%, physical neglect for 46.2%, and sexual abuse for 41.0%. There were 12.8% of participants meeting threshold levels for two subtypes, while 7.7% met threshold levels for three subtypes, 28.2% for four subtypes, and 12.8% for all five subtypes. In healthy controls, 66.7% did not meet any threshold level. Here, threshold levels were met for emotional abuse for 17.9%, emotional neglect for 5.1%, physical abuse for 5.1%, physical neglect for 23.1%, and sexual abuse for 2.6%. Table 1 presents participants' means on the assessments.

An initial repeated measures analysis of variance (ANOVA) showed significant interaction effects of Valence × Group, $F(3, 228) = 3.18$, $p = .031$, $\eta^2 = .040$, $\varepsilon = .88$, as well as Valence × Time × Group, $F(9, 684) = 2.73$, $p = .029$, $\eta^2 = .035$, $\varepsilon = .45$. Further significant main or interaction effects were not found (group: $F(1, 76) = 1.53$, $p = .220$, $\eta^2 = .020$; valence: $F(3, 228) = 1.33$, $p = .269$, $\eta^2 = .017$, $\varepsilon = .88$; time: $F(3, 228) = 2.53$, $p = .081$, $\eta^2 = .032$, $\varepsilon = .69$; Time × Group: $F(3, 228) = .23$, $p = .806$, $\eta^2 = .003$, $\varepsilon = .69$; Valence × Time: $F(9, 684) = .69$, $p = .597$, $\eta^2 = .009$, $\varepsilon = .45$). Because of the significant interaction effects, further 2 (Group: PTSD vs. healthy controls) × 4 (Time: 1,000-ms segments of stimuli presentation) repeated measures ANOVAs were computed for each valence separately (neutral, positive, physically threatening, socially threatening; see Figure 1).

For physically threatening words, the repeated measures ANOVA revealed a significant main effect of group, $F(1, 76) = 12.12$, $p = .001$, $\eta^2 = .138$. In PTSD patients, heart rate reactions were less pronounced than in healthy controls. The ANOVA did not show further significant effects (time: $F(3, 228) = .32$, $p = .684$, $\eta^2 = .004$, $\varepsilon = .54$; Time × Group: $F(3, 228) = 3.05$, $p = .061$, $\eta^2 = .039$, $\varepsilon = .54$). While there were no significant main effects of group and time in reaction to socially threatening words (group: $F(1, 76) = .51$, $p = .477$, $\eta^2 = .007$; time: $F(3, 228 = 2.38$, $p = .094$, $\eta^2 = .030$, $\varepsilon = .68$), the repeated measures ANOVA showed a significant interaction effect of time and group, $F(3, 228) = 3.47$, $p = .033$, $\eta^2 = .044$, $\varepsilon = .68$. Here, separate post hoc repeated measures ANOVAs revealed that heart rate reactions to socially threatening words did not show a significant variability in PTSD patients (time: $F(3, 114) = 2.19$, $p = .128$, $\eta^2 = .054$, $\varepsilon = .56$), while there was a significant main effect of time in healthy controls, $F(3, 114) = 4.01$, $p = .020$, $\eta^2 = .095$, $\varepsilon = .70$. Further post hoc *t* tests revealed that 3,000 to 4,000 ms poststimulus heart rate reactions to socially threatening words differed with a trend toward significance, with PTSD patients having more pronounced reactions than those found in healthy controls, $t(76) = 1.89$, $p = .063$. For neutral words, the ANOVA showed no significant main or interaction effects (time: $F(3, 228) = 1.53$, $p = .222$, $\eta^2 = .020$, $\varepsilon = .54$; group: $F(1, 76) = .05$, $p = .831$, $\eta^2 = .001$; Time × Group: $F(3, 228) = .08$, $p = .889$, $\eta^2 = .001$, $\varepsilon = .54$). Similarly, the repeated measures ANOVA for positive words did not show significant effects (time: $F(3, 228) = 1.38$, $p = .254$, $\eta^2 = .018$, $\varepsilon = .69$; group: $F(1, 76) = .22$, $p = .639$, $\eta^2 = .003$; Time × Group: $F(3, 228) = .22$, $p = .805$, $\eta^2 = .003$, $\varepsilon = .69$).

To examine different cardiac reactions in the group of PTSD patients to the different valenced words, an ANOVA with repeated measures on valence (neutral, positive, physically threatening, socially threatening) was conducted using mean heart rate changes over the course of the 4,000-ms stimulus presentation time of the PTSD patients. Here, a significant main effect of valence was found, $F(3, 114) = 3.79$, $p = .019$, $\eta^2 = .091$, $\varepsilon = .83$ (see Figure 2). Post hoc *t* tests (one-tailed) revealed that heart rate reactions in response to neutral, positive, and socially threatening words significantly differed from heart rate reactions to physically threatening words (physically threatening/neutral: $t(38) = 2.75$, $p = .004$; physically threatening/positive: $t(38) = 3.56$, $p = .001$; physically threatening/socially threatening: $t(38) = 2.59$, $p = .007$). Differences between the other valences did not show significant results (all *p*s > .05/6). In contrast, a similar ANOVA with repeated measures on valence (neutral, positive, physically threatening, socially threatening) using data of the healthy control group did not show a significant main effect of valence, $F(3, 114) = .46$, $p = .682$, $\eta^2 = .012$, $\varepsilon = .86$. Additionally, while all other mean heart rate changes differed significantly from zero (all *p*s < .05), the mean heart rate change in response to physically threatening words did not differ significantly from zero in PTSD patients, $t(38) = 1.26$, $p = .214$ (see Figure 2).

In the following, the associations of the psychopathological measurements and trauma history with physiological reactions to physically and socially threatening words in the sample of PTSD patients were exploratively examined. Interestingly, psychopathological or clinical measures were not associated with physiological reactions (see Table 2). However, CTQ scores showed significant and specific associations to cardiac reactions to physically and socially threatening words when contrasted with neutral words. While physical forms of child maltreatment were associated with reactivity to physically threatening words (physical neglect: $r = -.49$, $p = .012$; physical abuse: $r = -.51$, $p = .012$), reactions to socially threatening words were significantly correlated with the CTQ subscale emotional abuse ($r = -.43$, $p = .036$).

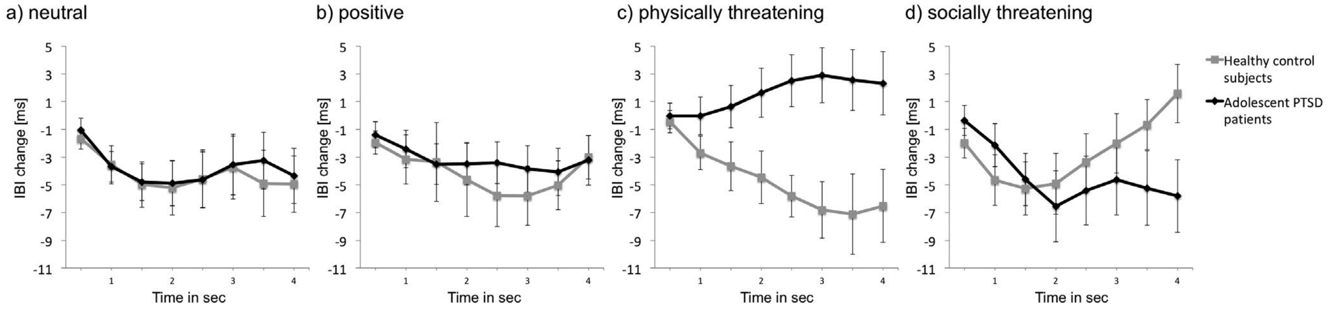

FIGURE 1 Means and standard errors of heart rate change in IBI (ms) across word presentation (4 s) in adolescent and young adult PTSD patients and healthy control subjects in response to (a) neutral, (b) positive, (c) physically threatening, and (d) socially threatening words. An increase in the IBI change scores indicates heart rate deceleration, and a decrease indicates heart rate acceleration

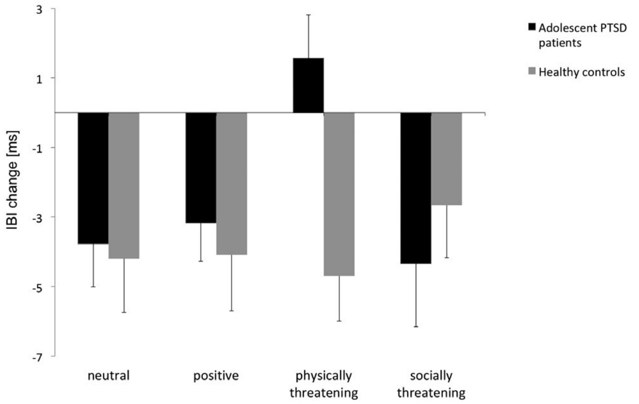

FIGURE 2 Means and standard errors of heart rate change in IBI (ms) relative to baseline for each group and for each word category (neutral, pleasant, physically threatening, socially threatening). An increase in the IBI change scores indicates heart rate deceleration, and a decrease indicates heart rate acceleration

4 | DISCUSSION

Because reports of cardiac alterations in adolescents and young adults are rare, ambiguous, and mostly restricted to victims of accidents, the present study aimed at contributing to a better understanding of cardiac reactions in adolescents and young adults with PTSD after CSA and/or CPA. In comparison to a healthy control group, we found that adolescents and young adults with PTSD related to child abuse presented with a blunted cardiac response to negative stimuli, and physically threatening stimuli in particular. In the PTSD group, cardiac reactions were significantly higher in response to socially threatening, neutral, and positive words than to physically threatening words. Interestingly, responses to socially threatening words showed differentiated courses over time in patients and controls. No differences in reaction to emotional words were present in the healthy control sample. Moreover, explorative analyses indicated that differentiated cardiac reactions to word categories were associated with different types of childhood traumatization. Reported effect sizes of the significant effects were small to medium.

In contrast to some early findings in adult subjects with PTSD (Adenauer et al., 2010; Buckley & Kaloupek, 2001; Pole, 2007), we found a blunted cardiac response in young PTSD patients compared to healthy control subjects specifically around physically threatening stimuli. Acceleration and variability of the heart rate in PTSD patients were significantly less pronounced for physically threatening cues than among the controls. A similar pattern was reported in some previous studies in specific groups of PTSD patients (Cuthbert et al., 2003; D'Andrea et al., 2013; Limberg et al., 2011; McTeague et al., 2010). A blunted physiological response to threat cues may reflect the fact that the human defense cascade to threat cues is not restricted to physiologically activating states of flight or fight but includes de-activating stages that are associated with dissociative responses. That is, numbing as well as a parasympathetic, rather than sympathetic, response may result in a physiological de-activation (Nijenhuis, Vanderlinden, & Spinhoven, 1998; Schauer & Elbert, 2010). Similarly, it has been proposed that psychophysiological hypoarousal can be a functionally appropriate peri-traumatic response in some types of traumatic experiences, including repeated and inescapable childhood trauma (e.g., D'Andrea et al., 2013; Lanius et al., 2002; Pole, 2007). In line with Lang's (1985) bioinformational theory of emotion, these trauma survivors should present with an associative trauma memory that includes a blunted physiological response. A reactivation of this memory through emotional cues should recapitulate the peri-traumatic physiological reactivity (e.g., Elbert, Rockstroh, Kolassa, Schauer, & Neuner, 2006; Keane et al., 1985; Lanius et al., 2002). Several studies have provided evidence for this blunted physiological reactivity caused by a stressor in PTSD patients compared to healthy controls (Arditi-Babchuk, Feldman, & Gilboa-Schechtman, 2009; Meyer, Albrecht, Bornschein, Sachsse, & Herrmann-Lingen, 2016). Additional studies showed that this pattern of physiological reactivity in PTSD patients was associated with dissociative symptoms (Lanius et al., 2002; Sack, Cillien, & Hopper, 2012), multiple incident traumatization

TABLE 2 PTSD patients' Pearson correlation coefficients for the association of psychopathological measurements and differences in heart rate reactivity in IBI (ms) to physically/socially threatening compared to neutral stimuli

	Physically threatening minus neutral	Socially threatening minus neutral
	***r* (*p*)**	***r* (*p*)**
Beck Depression Inventory, *M* (*SD*)	.00 (1.00)	.08 (.642)
UCLA PTSD Reaction Index, *M* (*SD*)	−.05 (.979)	.07 (.979)
Intrusion, *M* (*SD*)	.11 (.979)	.03 (.979)
Avoidance, *M* (*SD*)	−.01 (.979)	−.16 (.979)
Arousal, *M* (*SD*)	.09 (.979)	.05 (.979)
Trauma Symptom Checklist for Children		
Anxiety, *M* (*SD*)	.04 (.958)	−.06 (.958)
Depression, *M* (*SD*)	−.05 (.958)	.01 (.960)
Posttraumatic stress, *M* (*SD*)	.11 (.958)	−.19 (.958)
Sexual concerns, *M* (*SD*)	−.14 (.958)	−.18 (.958)
Dissociation, *M* (*SD*)	−.09 (.958)	−.01 (.960)
Anger, *M* (*SD*)	−.10 (.958)	.05 (.958)
Childhood Trauma Questionnaire, *M* (*SD*)	−.49 (.012)*	−.30 (.182)
Emotional abuse, *M* (*SD*)	−.26 (.224)	−.43 (.036)*
Emotional neglect, *M* (*SD*)	−.33 (.154)	−.25 (.224)
Physical abuse, *M* (*SD*)	−.51 (.012)*	−.07 (.782)
Physical neglect, *M* (*SD*)	−.49 (.012)*	−.26 (.224)
Sexual abuse, *M* (*SD*)	−.17 (.42)	−.05 (.786)

Note: N = 39. Physically threatening minus neutral: contrast of mean heart rate changes in IBI (ms) over the course of the 4,000-ms stimulus presentation time of physically threatening and neutral stimuli. Socially threatening minus neutral: contrast of mean heart rate changes in IBI (ms) over the course of the 4,000-ms stimulus presentation time of socially threatening and neutral stimuli. A negative correlation indicates that higher scores on the questionnaires were associated with smaller contrasts between physically or socially threatening words and neutral words, while a positive correlation indicates that higher scores on the questionnaires were associated with larger contrasts between physically or socially threatening words and neutral words. Within each questionnaire, Benjamini-Hochberg adjustment of significance levels was applied.

$^{*}p < .05$.

(Cuthbert et al., 2003; McTeague et al., 2010), and early developmental occurrence of traumatization (D'Andrea et al., 2013; Quevedo et al., 2010). Additionally, blunted reactivity has also been found in victims of child maltreatment (Heleniak, McLaughlin, Ormel, & Riese, 2016; MacMillan et al., 2009). Accordingly, cardiac reactions to physically threatening contrasted with neutral words were associated with physical types of childhood traumatization. Contrasted with previous reports (Lanius et al., 2002; Sack et al., 2012), however, dissociative symptoms were not associated with cardiac reactivity in the present study. In line, several studies have shown no impact of high dissociative tendencies on the physiology of PTSD (Halligan, Michael, Wilhelm, Clark, & Ehlers, 2006; Kaufman et al., 2002; Nixon, Bryant, Moulds, Felmingham, & Mastrodomenico, 2005). Hence, the underlying mechanisms of blunted physiological reactivity in adolescent and young adult PTSD patients after CSA/CPA need to be further examined.

To our knowledge, the present study is the first to examine cardiac reactions to emotional stimuli in adolescents and young adults with PTSD diagnosed after child abuse. Contrasted with previous reports of elevated heart rate reactions in child PTSD patients (Saltzman et al., 2005; Scheeringa et al., 2004) as well as reports of no alterations in heart rate reactions to idiosyncratic trauma scripts (Kirsch et al., 2015), the results of the present study provide evidence that a physiologically blunted subtype of PTSD may also exist in adolescents and young adults similar to what has been proposed for adult PTSD (D'Andrea et al., 2013). Here, age may play a crucial role in the formation of the physiological response. It may be suggested that biological and cognitive maturation promote a differentiated processing of threating stimuli, particularly threatening words. Accordingly, elevated hear rate reactions were reported in children rather than in adolescents or adults with PTSD (Saltzman et al., 2005; Scheeringa et al., 2004). However, some caution is warranted accepting our suggestions about a physiologically blunted subtype of PTSD. Because the physiology of the defense cascade is characterized by both sympathetic and parasympathetic activation (D'Andrea et al., 2013), further studies are needed to validate our findings and conclusions using a wide range of physiological and experiential parameters (e.g., cardiovascular and electrodermal measures).

Interestingly, while physiological reactions to physically threatening words as discussed above were generally blunted, the course of the physiological reaction to socially threatening words differed between PTSD patients and healthy controls. Whereas healthy controls showed an initial heart rate increase during the first 2 s of word presentation followed by a heart rate decrease in the next 2 s, PTSD patients' initial heart rate increases persisted over time, which may represent an unresponsive or tonic immobility associated with tachycardia (Schauer & Elbert, 2010). However, because it is very similar to the physiological reactions to positive and neutral words and did not differ significantly within the patient sample, the invariable elevated heart rate in reaction to socially threatening words in adolescents and young adults with PTSD after CSA/CPA must be interpreted with caution. With respect to the specific associations of cardiac reactivity to physically and socially threatening words with physical and emotional forms of child maltreatment, our findings may point to the inequality of physiological reactions to physical and emotional reminders of maltreatment. This is in line with previous studies that emphasized the role of emotional maltreatment in the etiology of PTSD (Spertus et al., 2003; Teicher et al., 2006). In addition, analyses of ERPs in response to the emotionally threatening words in the present study showed augmented early late positive potential amplitudes for socially threatening stimuli in PTSD patients, while there were no modulations within the healthy control group (Klein et al., 2019). This may also suggest a differentiated and more elaborate processing of socially negative words in PTSD patients after CSA/CPA that may go along with a persisting cardiac response. However, ERP data were to some extent in contrast to the findings of cardiac reactions. In particular, ERP differences between PTSD patients and healthy controls in reaction to physically threatening words could not be found. Hence, the main result of the present study (i.e., blunted physiological reactivity in PTSD patients) was not supported by ERP analyses. These contradictory findings challenge the reliability of the paradigm used. Obviously, the stimuli and the chosen design were not able to provide clear evidence of neuro- and peripheral physiological differences between as well as within the samples. Therefore, a comprehensive investigation of psychophysiological reactions to different types of threatening stimuli in PTSD patients would be worthwhile in further studies.

In the present study, standardized nontrauma-related words were used as stimuli. In doing so, we were able to replicate prior findings reporting differences between PTSD subjects and healthy controls in reaction to standardized rather than idiosyncratic stimuli (Ehlers et al., 2010; Foa et al., 1989; Keane et al., 1985). In line with suggestions by Ehlers et al. (2010), we assume that these results indicate a generalization of learned fear responses to generally negative stimuli that do not necessarily resemble the original traumatic situation. Although they must be interpreted with caution, the differences in reaction to physically threatening standardized stimuli and socially threatening stimuli as well as the specific associations to trauma history may point to the existence of two coexisting fear or defense networks in adolescents and young adults with PTSD after CSA/CPA. It is possible that one network tends to process physically threatening stimuli and the other socially threatening stimuli. Again, this emphasizes the potential relevance of processes related to emotional rather than physical or sexual maltreatment in the etiology of PTSD (Spertus et al., 2003; Teicher et al., 2006). Effect sizes in the current study that used standardized words for each threatening category have already been found to be small to medium. It is likely that differentiated cardiac reactions in response to physically and socially threatening compared to neutral and positive words may be more pronounced when using idiosyncratic stimuli consisting of words that were collected with respect to individual histories of physical, sexual, and emotional abusive acts.

The present study has several limitations. The validity of the current study is weakened by the fact that no ratings were obtained as to what extent the participants perceived the words as socially or physically threatening, positive, or neutral. Therefore, it remains speculative whether the differences in heart rate reactivity were actually due to physical or social threat. However, the words were assessed in a previous study and selected on the basis of their valence and their potential to threaten physical and social integrity, increasing the likelihood of a valid measurement of physiological reactions to physical and social threat (Wabnitz et al., 2012). In addition, as the trigger appeared infrequently and the participants had to react to it as fast as possible, the passive reading paradigm became more like an intermittent reaction task. Hereby, the attention of the participants was unintentionally shifted toward the magenta dot and away from the emotional words. Obrist, Webb, and Sutterer (1969) could already show that, in a simple reaction time task, cardiac deceleration occurs just before and during the second that the behavioral response is made. Accordingly, the psychophysiological responses in our study might be additionally modulated by the demands of the task instead of processing of the emotional stimuli, although this effect should occur unconditionally across conditions and groups. Further investigations should consider other strategies to ensure that the participants focus on the stimuli presented to them. In addition, the ITIs in the current pradigm were rather short (i.e., 500 ms); therefore, we cannot preclude that order effects may have confounded our findings because the ITI served as baseline for the following heart rate reactions to the emotional words. Although randomization may have attenuated the influences of order effects, upcoming studies should use longer ITIs to prevent these effects. Next, the groups differed with respect to medication, which potentially may have confounded the effects. However, there is no indication that differential heart rate reactivity is generally affected by antidepressant medication (Adenauer et al., 2010). Recruitment of samples without medication or increased sample sizes would allow for subgroup analyses depending on medication status. Additionally, the generalizability of our findings is restricted by the high proportion of female participants in the sample. Even though men experience traumatic events more frequently, women are more often confronted with highly noxious events such as rape and sexual abuse and show a higher risk of developing PTSD after the experience of a traumatic event (Gavranidou & Rosner, 2003; Perkonigg, Kessler, Storz, & Wittchen, 2000). Therefore, the unequal proportion of men and women in the present study reflects the sex ratio in clinical samples. Additionally, our correlation analyses were conducted for explorative purposes only and may be limited by the small sample size and inflation of Type I error that we addressed using a rather liberal adjustment. Furthermore, while we tried to balance all stimuli for word frequency and length across conditions, we could not ascertain appropriate word frequency parameters for the swear words used as socially threatening stimuli, which might confound the effects. Even if there might be systematic differences based on the CELEX database for written German, the average word frequency for swear words is difficult to estimate. Swear words are mostly used in verbal communication, and to our knowledge there is no adequate measurement of frequency of swear words in a general conversation. Hence, although a previous study using the same stimulus set indicated that word frequency had no effect on ERPs (Wabnitz et al., 2012), lower frequency as well as violation of social norms may have affected heart rate reactivity to socially threatening words. With respect to the latter, heart rate reactions of the healthy control sample did not indicate a specific effect of swear words due to violation of social norms. Finally, the results conflict with previous research showing that negative stimuli elicit higher increases in heart rates than positive or neutral stimuli (Wessa, Karl, & Flor, 2005). Emotional words might not elicit the same responses as emotional pictures, sounds, scripts, or audio, suggesting the importance of the type of stimuli used for investigating emotional processing through electrocardiography. Nevertheless, the physiological reactivity to physically and socially threatening words seems to reflect a functionally appropriate response after repeated and inescapable childhood trauma and therefore might be specific to these trauma survivors.

Our study is in line with previous research, suggesting a differential cardiac reactivity to negative stimuli in PTSD patients, which may be the result of altered fear-network processing. Specifically, adolescent and young adult participants with PTSD showed differentiated reactivity patterns to physically threatening words. Additionally, our results were indicative of an altered reactivity to socially threatening words in patients when compared to healthy controls. This may point to the relevance of individual trauma history for physiological reactions. Our study is, to our knowledge, among the first studies to expand this field of research to adolescent and young adult victims of CSA and/or CPA suffering from PTSD. The present findings may help to break down the basic principles of altered psychophysiology in PTSD to find specific characteristic features of adolescent and young adulthood PTSD.

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