



Are you angry at me? Negative interpretations of neutral facial expressions are linked to child maltreatment but not to posttraumatic stress disorder

Monique C. Pfaltz, Sandra Passardi, Bianca Auschra, Natalia E. Fares-Otero, Ulrich Schnyder and Peter Peyk

Department of Consultation-Liaison Psychiatry and Psychosomatic Medicine, University Hospital Zurich, University of Zurich, Zurich, Switzerland

ABSTRACT

Background: Individuals with a high prevalence of child maltreatment, e.g. those with borderline personality disorder, tend to see neutral facial expressions as negative.

Objective: Our aim was to assess whether this bias is present in individuals with posttraumatic stress disorder (PTSD) and whether it is linked to child maltreatment.

Methods: Thirty-nine PTSD participants, 44 traumatized and 35 non-traumatized healthy controls watched 300 one-second movies showing 30 neutral and 270 emotional facial expressions, and indicated whether they interpreted each as a neutral or as one of nine emotional expressions.

Results: PTSD individuals did not perform differently than the two control groups in the recognition and interpretation of neutral facial expressions (p 's < .300). Higher levels of childhood sexual and emotional abuse, and physical neglect were linked to more interpretations of neutral facial expressions as contempt (p 's < .043), and (for sexual abuse and physical neglect) to more interpretations of neutral facial expressions as anger (p 's < .014). Comparisons of statistical model fits suggested that childhood sexual abuse was the most relevant predictor of recognition accuracy in our sample. Alexithymia, state dissociation, interpersonal trauma, and number of experienced trauma types were not associated with deficits in the interpretation of neutral expressions.

Conclusions: Child maltreatment, especially sexual abuse, may shape the interpretation of neutral facial expressions. Future research should explore whether the observed biases extend to real-life situations. If so, therapists might improve the therapeutic relationship with patients with a history of child maltreatment by paying more attention to their own non-verbal communication and their patients' responses to it. Furthermore, similarly to individuals with high depressive and high social anxiety symptoms, facial expression recognition training might counteract negativity bias in individuals with a history of childhood (sexual and emotional) abuse, and (physical) neglect.

¿Estás enojado conmigo? Las interpretaciones negativas de las expresiones faciales neutras están relacionadas con el maltrato infantil pero no con el trastorno de estrés postraumático

Antecedentes: las personas con una alta prevalencia de maltrato infantil, por ejemplo, aquellos con trastorno límite de la personalidad, tienden a ver las expresiones faciales neutras como negativas.

Objetivo: Nuestro objetivo fue evaluar si este sesgo está presente en personas con trastorno de estrés postraumático (TEPT) y si está relacionado con el maltrato infantil.

Métodos: Treinta y nueve participantes con TEPT, 44 controles sanos traumatizados y 35 no traumatizados vieron 300 películas de un segundo que mostraban 30 expresiones faciales neutras y 270 emocionales, e indicaron si interpretaron cada una de ellas como una de las nueve expresiones emocionales.

Resultados: los individuos con TEPT no tuvieron un desempeño diferente al de los dos grupos de control en el reconocimiento e interpretación de expresiones faciales neutras (p 's < .300). Los niveles más altos de abuso sexual y emocional infantil y negligencia física se vincularon a interpretar más las expresiones faciales neutras como desprecio (p 's < .043) y (por abuso sexual y negligencia física) a interpretar más las expresiones faciales neutras como ira (p 's < .014). Las comparaciones de los ajustes estadísticos del modelo sugirieron que el abuso sexual infantil fue el predictor más relevante de precisión de reconocimiento en nuestra muestra. La alexitimia, la disociación del estado, el trauma interpersonal y el número de tipos de trauma experimentados no se asociaron con déficits en la interpretación de las expresiones neutras.

Conclusiones: El maltrato infantil, especialmente el abuso sexual, puede dar forma a la interpretación de las expresiones faciales neutras. La investigación futura debería explorar si los sesgos observados se extienden a situaciones de la vida real. De ser así, los terapeutas podrían mejorar la relación terapéutica con pacientes con antecedentes de maltrato infantil

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关键词

表情识别; 负性认知偏差; 中性面部表情; 创伤后应激障碍; 童年创伤; 模糊社会刺激

HIGHLIGHTS

- Individuals with posttraumatic stress disorder (PTSD) do not show abnormalities in the recognition and interpretation of neutral facial expressions.
- Childhood sexual and emotional abuse, and physical neglect are linked to more interpretations of neutral facial expressions as contempt and anger.
- Childhood sexual abuse seems to be the most relevant predictor of recognition accuracy for neutral expressions.

prestando más atención a su propia comunicación no verbal y a las respuestas de sus pacientes. Además, de manera similar a las personas con síntomas depresivos y de ansiedad social, el entrenamiento de reconocimiento de la expresión facial podría contrarrestar el sesgo de negatividad en personas con antecedentes de abuso infantil (sexual y emocional) y negligencia (física).

你在生我的气吗？对中性面部表情的负面解读与童年虐待有关，但与创伤后应激障碍无关

背景：虐待儿童流行率高的个体，如边缘性人格障碍患者，倾向于将中性的面部表情视作消极的。

目的：我们旨在评估这种偏差是否存在于创伤后应激障碍（PTSD）患者中，以及是否与虐待儿童有关。

方法：39名PTSD被试，44名遭受过创伤和35名未遭受过创伤的健康对照被试观看了300个分别时长1秒的影片片段，其中呈现了30种中性和270种有情绪的面部表情。被试指出他们是将每种表情理解为中性还是九种情感表情之一。

结果：PTSD个体在识别和解读中性面部表情方面的表现与两个对照组无差异（均为 $p < .300$ ）。更高水平的童年期性虐待，精神虐待以及躯体忽视与更多把中性面部表情解读为轻蔑相关（ $p < .043$ ），性虐待和躯体忽视与更多把中性面部表情解读为愤怒相关（ $p < .014$ ）。比较统计模型拟合指数表明，童年性虐待是我们样本中识别准确度最大的预测因素。述情障碍，状态解离，人际创伤和创伤经历类型的数目与中性表情解读的缺陷无关。

结论：童年虐待，特别是性虐待，可能会塑造对中性面部表情的解读方式。未来的研究应该探究观测到的偏差是否会扩展到现实生活中。如果是这样，治疗师可以通过更加注意他们自己的非语言交流以及患者对此的反应来改善与有童年虐待史的患者的治疗关系。此外，与具有高度抑郁和高度社交焦虑症状的个体相似，面部表情识别训练可以抵消有（性和情感）童年虐待和（躯体）忽视病史的个体的消极偏见。

1. Introduction

Neutral facial expressions can be interpreted and responded to in different ways, due to lacking or potentially ambiguous information on the emotional state of the person or her relationship towards the interaction partner. The ability to detect and differentiate neutral from emotional facial expressions develops rather late in childhood (Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2007). Young children tend to wrongly attribute sadness or joy to neutral facial expressions. There is evidence that processing of neutral facial expressions involves different neural structures than processing of emotional facial expressions (Fusar-Poli et al., 2009; Jehna et al., 2011). During childhood, neutral facial expressions can be perceived as threatening and lead to increased negative affect, decreased positive affect, and physiological stress reactions (Mesman, van IJzendoorn, & Bakermans-Kranenburg, 2009). Individuals with autism spectrum disorders (Eack, Mazefsky, & Minshew, 2015), depression (Bourke, Douglas, & Porter, 2010), schizophrenia (Kohler et al., 2003), and borderline personality disorder (BPD) (Daros, Zakzanis, & Ruocco, 2013; Mitchell, Dickens, & Picchioni, 2014) show abnormal amygdala responses to neutral facial expressions (Donegan et al., 2003; Harms, Martin, & Wallace, 2010; Sheline et al., 2001) and tend to interpret them as negative.

Studies on facial expressions in PTSD have, to date, focused on deficits in recognition of positive

and negative facial expressions (Passardi et al., 2018; Poljac, Montagne, & de Haan, 2011) and on theory of mind (Mazza et al., 2012; Nazarov et al., 2014; Nietlisbach, Maercker, Rösler, & Haker, 2010; Schmidt & Zachariae, 2009); a construct related to but not identical with emotion recognition. They found deficits in the recognition of positive (Passardi et al., 2018) and negative (fearful and sad) emotions (Poljac et al., 2011) and inconsistent results regarding theory of mind, ranging from generalized deficits (Mazza et al., 2012; Schmidt & Zachariae, 2009) to no abnormalities (Nazarov et al., 2014; Nietlisbach et al., 2010). Only one study has analysed recognition of neutral facial expressions in adults with PTSD and found no differences compared to healthy controls (Nazarov et al., 2014). However, this study used static images, only depicting the ocular region of the face and has assessed the recognition of complex (positively valenced, negatively valenced and neutral) mental states as part of a theory of mind task. While no study has assessed interpretation of neutral (whole) facial expressions in adults with PTSD, as seen in everyday situations, there is evidence that individuals with PTSD – on a cortical level – fail to differentiate between angry and neutral facial expressions (when asked to watch the expressions passively). The authors interpreted this as difficulty to distinguish between threat and non-threat stimuli (Felmingham, Bryant, & Gordon, 2003).

There is evidence in PTSD-related populations for abnormalities in the interpretation of neutral facial expressions. For example, individuals with BPD –

who show a high prevalence of trauma and maltreatment during childhood (Battle et al., 2004; Wingenfeld et al., 2011) – interpret neutral facial expressions as more negative than healthy controls and tend to interpret them as anger (Daros et al., 2013; Mitchell et al., 2014) or sadness (Meehan et al., 2017). Likewise, individuals with dissociative identity disorder show high rates of childhood traumatization. When in a trauma-related emotional state, they perceive neutral faces as highly threatening (Schlumpf et al., 2013). Aligning with that, individuals with PTSD show high rates of child maltreatment, and child maltreatment is linked to negative interpretations of neutral facial expressions in children (Pollak, Cicchetti, Hornung, & Reed, 2000) and to impaired recognition of neutral facial expressions in adults (Wagner & Linehan, 1999). In individuals with child maltreatment, neutral expressions might trigger memories of neglect or abuse, potentially contributing to the above-mentioned findings (Daros et al., 2013; Meehan et al., 2017; Mitchell et al., 2014; Pollak et al., 2000; Schlumpf et al., 2013; Wagner & Linehan, 1999).

Other factors that might influence the interpretation of neutral facial expression are alexithymia, the number of experienced trauma types (NOET), or dissociation. Individuals with PTSD show a heightened prevalence of alexithymia (difficulties describing and identifying feelings (Sifneos, 1973)), which is related to emotion recognition deficits in healthy and clinical populations [for meta-analysis, see Frewen, Dozois, Neufeld, and Lanius (2008)]. In particular, there is some evidence that alexithymia might be associated with deficits in the recognition of neutral facial expressions in clinical and healthy populations, although results are inconclusive [for review see Grynberg et al. (2012)]. In previous analyses of the same sample that was assessed in the present manuscript, we had found that higher NOET and higher state dissociation were linked to deficits in the recognition of positive facial expressions (Passardi et al., 2018).

The present study aimed at assessing whether individuals with PTSD interpret neutral facial expressions more negatively than controls by using stimuli close to facial expressions found in everyday life. We used the same data set for which results on recognition of positive and negative emotions in individuals with PTSD have already been reported (Passardi et al., 2018). Based on previous studies in individuals with child maltreatment (Pollak et al., 2000; Wagner & Linehan, 1999) and individuals with BPD (Daros et al., 2013; Meehan et al., 2017; Mitchell et al., 2014), we hypothesized that individuals with PTSD would show poorer recognition of neutral expressions and would rate neutral expressions more often as negative (i.e. as expressions of anger, contempt, fear, sadness, disgust, or embarrassment) compared to a healthy traumatized (TC) and a healthy non-traumatized control group (HC). In addition, we

aimed at exploring whether possible abnormalities in the interpretation of neutral facial expressions are more closely associated with maltreatment during childhood than to the diagnosis of PTSD. Assuming that biases seen in BPD or dissociative identity disorder (Daros et al., 2013; Meehan et al., 2017; Mitchell et al., 2014; Schlumpf et al., 2013) might be linked to child maltreatment and associated learning processes (Guitart-Masip et al., 2009; Pollak et al., 2000; Wagner & Linehan, 1999), we predicted that individuals with more traumatic childhood experiences would interpret facial expressions more often as negative than individuals with fewer traumatic childhood experiences. To preclude that interpreting neutral expressions as more negative was due to a general tendency to misinterpret facial expressions, we also analysed confusing an emotional expression with a neutral expression and expected no differences between individuals with PTSD and controls. Since NOET, alexithymia, and state dissociation are related to emotion recognition deficits in PTSD (Passardi et al., 2018; Passardi, Peyk, Rufer, Wingenbach, & Pfaltz, 2019), we included these variables in the analysis as possible influencing factors. We furthermore included interpersonal trauma as an additional variable to differentiate between the impact of childhood trauma versus interpersonal trauma. We used reaction times (RTs) as additional, exploratory outcome measure for all analyses.

2. Method

2.1. Participants

Participants were recruited via online platforms, newspaper advertisements, mailing lists, postings, from a pool of former study participants, from patients of the University Hospital Zurich, and via external mental health professionals. Individuals aged 18–65 years with normal or corrected-to-normal vision that are native German speakers or of equivalent proficiency with a verbal IQ > 70 [according to a German multiple-choice vocabulary test, WST; Schmidt and Metzler (1992)] were included. Exclusion criteria were antipsychotic, benzodiazepine or tricyclic antidepressant medication, acute suicidality, lifetime psychotic symptoms, substance abuse or dependency (past 12 months), and physical health problems affecting psychophysiological measurements [results reported in Passardi et al., 2019]. The PTSD group met current PTSD diagnosis according to the DSM-5 (American Psychiatric Association, 2013). Lifetime PTSD diagnosis and current mental disorders were exclusion criteria for the control groups. HC had never experienced a trauma according to DSM-5 criteria, whereas TC had experienced at least one traumatic event.

After the diagnostic interview, 15 out of 54 potential PTSD participants were excluded due to current or lifetime psychotic symptoms ($n = 3$), current

substance use disorders ($n = 4$), not meeting full PTSD criteria ($n = 7$), and insufficient German proficiency ($n = 1$). Eight out of 52 potential TC were excluded due to current or lifetime psychotic symptoms ($n = 2$), current substance abuse ($n = 1$) or other psychiatric disorders ($n = 3$), and lifetime PTSD diagnosis ($n = 2$). Four out of 39 potential HC were excluded due to current substance abuse ($n = 1$), other psychiatric disorders ($n = 2$), or past trauma experience ($n = 1$). This resulted in group sizes of 39 PTSD participants, 44 TC and 35 HC.

Table 1 illustrates participants' characteristics. Participants in the PTSD group reported more interpersonal trauma than participants in the TC group. Index traumas were accidents (PTSD: $n = 7$; TC: $n = 18$), natural disasters (PTSD: $n = 0$; TC: $n = 3$), non-sexual assault by family members or acquaintances (PTSD: $n = 7$; TC: $n = 5$), non-sexual assault by strangers (PTSD: $n = 2$; TC: $n = 3$), sexual assault by family members or acquaintances (PTSD: $n = 15$; TC: $n = 2$), sexual assault by strangers (PTSD: $n = 2$; TC: $n = 2$), life-threatening illness (PTSD: $n = 1$; TC: $n = 2$), work-related trauma (PTSD: $n = 0$; TC: $n = 2$), mix of different trauma types (PTSD: $n = 1$; TC: $n = 2$), and other traumatic experiences (PTSD: $n = 4$; TC: $n = 4$). Comorbid mental disorders in PTSD participants were major depression ($n = 23$), dysthymia ($n = 10$), panic disorder ($n = 11$), agoraphobia ($n = 16$), social phobia ($n = 7$), generalized anxiety disorder ($n = 7$), obsessive-compulsive disorder ($n = 2$), and bulimia nervosa ($n = 1$). The study was approved by the Cantonal Ethics Committee of Zurich. All participants gave written informed consent prior to participation.

2.2. Diagnostic instruments and psychometric measures

Current and past PTSD diagnoses were determined by the German Clinician-Administered PTSD Scale for DSM-5 (CAPS) (Müller-Engelmann et al., 2018). Internal consistencies for symptom cluster severity scores were high (re-experiencing: $\alpha = 0.91$, avoidance: $\alpha = 0.81$, negative alterations in cognitions and mood: $\alpha = 0.92$, hyperarousal: $\alpha = 0.87$). Current diagnoses of other mental disorders were ascertained by the Mini International Neuropsychiatric Interview (M.I.N.I.) (Ackenheil, Stotz-Ingenlath, Dietz-Bauer, & Vossen, 1999). We assessed trauma history with the Posttraumatic Diagnostic Scale (PDS), part II (Ehlers, Steil, Winter, & Foa, 1996).

Child maltreatment was assessed by the German short version of the Childhood Trauma Questionnaire (CTQ) (Wingenfeld et al., 2010), comprising 28 items rated on five-point scales belonging to five subscales (emotional abuse, physical abuse, sexual abuse, emotional neglect, physical neglect). Internal consistency for the total score and subscores were high (total score: $\alpha = 0.90$, emotional abuse subscale: $\alpha = 0.92$, physical abuse subscale: $\alpha = 0.82$, sexual abuse subscale: $\alpha = 0.96$, emotional neglect subscale: $\alpha = 0.93$), except for the physical neglect subscale ($\alpha = 0.68$), which is in line with the literature (Wingenfeld et al., 2010). To determine NOET, we counted the number of different trauma types according to the Posttraumatic Diagnostic Scale (PDS), part II (Ehlers et al., 1996).

State dissociation during the emotion recognition task was assessed with the German version of the Responses to Script-Driven Imagery Scale (RSDI) (Hopper, Frewen, Sack, Lanius, & van der Kolk,

Table 1. Participants' characteristics.

	PTSD (N = 39)		TC (N = 44)		HC (N = 35)		Group comparisons ^b
	N	%	N	%	N	%	
Female gender	29	74	15	66	9	74	ns
Interpersonal trauma	29	74	14	32	0	0	PTSD > TC ^a
Type II trauma (long-lasting/repeated)	25	64	5	11	0	0	PTSD > TC ^a
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
Age	38.7	12.8	36.5	12.0	36.6	10.2	ns
School years	11.4	2.6	12.1	3.3	12.4	3.3	ns
BDI ^c	24.5	8.8	3.3	3.3	2.6	5.0	PTSD > TC ^a , PTSD > HC ^a
PDS ^d	36.3	8.7	8.7	7.1	-	-	PTSD > TC ^a
CTQ ^e emotional abuse	13.5	6.6	6.7	3.1	6.8	3.1	PTSD > TC ^a , PTSD > HC ^a
CTQ physical abuse	9.8	5.3	6.2	2.5	5.4	0.9	PTSD > TC ^a , PTSD > HC ^a
CTQ sexual abuse	15.2	8.3	6.2	3.1	5.3	0.9	PTSD > TC ^a , PTSD > HC ^a
CTQ emotional neglect	16.9	5.5	11.3	5.2	9.6	4.5	PTSD > TC ^a , PTSD > HC ^a
CTQ physical neglect	9.9	3.8	7.0	2.7	6.2	1.5	PTSD > TC ^a , PTSD > HC ^a
NOET ^f	3.5	1.6	2.0	1.0	-	-	PTSD > TC ^a
TAS-20 ^g	56.2	12.4	37.2	8.1	37.4	8.7	PTSD > TC ^a , PTSD > HC ^a
RSDI ^h	3.5	4.8	0.30	0.8	0.3	1.0	PTSD > TC ^a , PTSD > HC ^a

^a $p < .001$

^bPTSD: Posttraumatic stress disorder; TC: Traumatized healthy controls

HC: Non-traumatized healthy controls; ns: not significant

^cBDI: Beck Depression Inventory

^dPDS: Posttraumatic Diagnostic Scale (modified according to DSM-5)

^eCTQ: Childhood Trauma Questionnaire

^fNOET: Number of experienced trauma types

^gTAS-20: Toronto Alexithymia Scale

^hRSDI: Responses to Script-Driven Imagery Scale

2007), a brief self-report measure of state PTSD and dissociative symptoms. For this study, we only used the dissociative symptoms subscale (4 items) which showed high internal consistency ($\alpha = 0.91$).

Alexithymia was assessed with the Toronto Alexithymia Scale [German version, TAS-20, Bagby, Parker, and Taylor (1994)], a self-report measure with 20 items. Internal consistency was high ($\alpha = 0.92$).

2.3. Emotion recognition task

Participants watched 300 filmed facial emotion expressions (plus 10 practice trials) from the Amsterdam Dynamic Facial Expression Set-Bath Intensity Variations (ADFES-BIV) (Wingenbach, Ashwin, & Brosnan, 2016), the adaptation of the ADFES (Van der Schalk, Hawk, Fischer, & Doosje, 2011), presented in E-Prime 2.0 (Psychological Software Tools Inc.) Data from the same sample and the same paradigm are presented in two other publications that analysed recognition of negative and positive facial expressions (Passardi et al., 2018) and facial mimicry in a subsample of the current study (Passardi et al., 2019). Two hundred seventy of the one-second-video sequences showed a facial expression changing from neutral into one of the nine emotions (joy, pride, sadness, fear, anger, disgust, contempt, embarrassment, or surprise). Data for these sequences are reported in (Passardi et al., 2018). Thirty video sequences showed neutral expressions of one of the five male and five female actors that remained neutral for the total video duration. After each video, a blank screen appeared for 500 ms, followed by the answer screen, which contained ten response fields, each labelled with 'neutral' or one of the nine emotional expressions. Participants were asked to identify as quickly as possible which of the neutral or emotional expressions had been presented by clicking on the respective field. By asking participants to answer as quickly as possible, we intended to prevent participants from reflecting on the presented expressions and on their answers and to have them decide rather spontaneously, which is closer to everyday situations. Thereafter, a blank screen appeared for 500 ms. Each trial started with a fixation cross in the middle of the screen, remaining for 1000 ms, 1500 ms, 2000ms, 2500 ms or 3000 ms (randomized duration). Correct responses and response times (in ms) were recorded by means of E-Prime.

2.4. Procedure

Participants were screened for inclusion and exclusion criteria by phone. For potential TC and PTSD participants, we administered the PDS, part III during this phone interview to assess presence and severity of PTSD symptoms. Since at the time of data collection, PDS for DSM-5 was not available, we created a modified PDS version to cover the DSM-5 criteria for

PTSD. Eligible participants scheduled an appointment for a first assessment in the laboratory, during which graduate psychology students administered the CAPS-5 and the M.I.N.I. Prior to completing each part of the study, participants were informed about the procedure. They furthermore received a written study information and completed an informed consent form.

Prior to starting with the emotion recognition part of the study, which took place within one week after the interview, participants completed the German versions of the Beck Depression Inventory (Hautzinger, Bailer, Worall, & Keller, 1994), the State-Trait Anxiety Inventory (Laux, Glanzmann, Schaffner, & Spielberger, 1981; to be reported elsewhere), the Toronto Alexithymia Scale (Bagby et al., 1994), the short version of the Symptom Checklist (Klaghofer & Brähler, 2001; to be reported elsewhere), the Multidimensional Inventory of Dissociation (Dell, 2006; to be reported elsewhere), and the Dissociative Experiences Scale (Freyberger, Spitzer, & Stieglitz, 1999; to be reported elsewhere). During the second part of the study, participants first completed the WST. Thereafter and for the rest of the study, facial electromyography [see Passardi et al., 2019 for results], electrodermal activity, respiratory rate, and electrocardiogram were recorded. During the first 5 min, baseline psychophysiological measures were recorded. Participants then completed the emotion recognition task. Then, they completed self-ratings on their current emotional state (joy, anger, fear, disgust, sadness, surprise, contempt, shame, pride, neutral) on a scale ranging from 0 (not at all) to 5 (extremely), the Emotion Regulation Questionnaire (Abler & Kessler, 2009; reported in Freyberger et al., 1999), the Dissociation-Tension Scale acute (Stiglmayr, Braakmann, Haaf, Stieglitz, & Bohus, 2003; to be reported elsewhere), and the RSDI (Hopper et al., 2007). Finally, they were reimbursed for their participation.

2.5. Statistical analyses

Statistical analyses were carried out in R version 3.6.1 (R Core Team, 2019) and SPSS (IBM SPSS statistics, version 25).

For each participant, the number of correctly identified neutral expressions (the response accuracy, ACC) was calculated. This count variable was assumed to follow a binomial distribution but proved to be overdispersed (with a dispersion parameter $\phi = 7.24$, corresponding to the sum of the Pearson residuals divided by the residual degrees of freedom). To compare the number of correct responses between diagnostic groups (PTSD, TC, HC) accounting for overdispersion, a beta-binomial generalized linear model with a logit link was calculated using the R-package 'aod' (Lesnoff & Lancelot, 2012), modelling the dispersion parameter as a random effect of the diagnostic group.

Median reaction times (RT) per subject were positively skewed and were therefore compared between diagnostic groups using a gamma generalized linear model with a log link as provided by the standard 'stats' R-package. RT analyses were based on correct trials only.

Child maltreatment (CTQ subscale scores), NOET, interpersonal trauma, TAS-20, and RSDI were substantially correlated with diagnostic group and could therefore not be entered into the same statistical model. To obtain estimates of their impact on the dependent variables (ACC and RT), we additionally conducted the described analyses using groups based on these measures and compared the model fit (AIC: Akaike information criterion) of the resulting models (alternative models) with the original group design based on diagnostic groups (standard model). To remove the influence of the number of estimated parameters from the calculated model fit, we coerced grouping variables to have only two gradations (and approximately similar group sizes, see appendix, Table A1) for the purpose of fit comparison. We thus performed one analysis for diagnostic group with a merged healthy and trauma control group vs. the PTSD group, one for each of the five CTQ subscales with groups based on median splits of the CTQ subscales, one analysis for number of experienced trauma types (0–2 trauma types vs. 3 or more trauma types), one analysis for interpersonal trauma (no trauma or non-interpersonal trauma vs. interpersonal trauma), one analysis based on a median split of the RSDI, and one based on a median split of the TAS-20. To account for multiple testing, Bonferroni-Holm corrections were applied for these ten models. Odds ratios (exponentiations of the beta coefficients from the regression model termed ' $exp(b)$ ') were calculated as effect size measures and are reported with their confidence intervals.

For the standard model and all alternative models with a better model fit than the standard model, confusion patterns in recognition of neutral expressions were analysed using a set of generalized linear models with beta-binomial distributions and logit link functions, one for each of the nine possible misidentifications with the total number of relevant trials (30) as reference value. The multinomial problem was thus parametrized as a series of (beta-) binomial contrasts as recommended by Dobson and Barnett (Dobson & Barnett, 2008), with the respective grouping variable (diagnostic group, CTQ median-split or interpersonal trauma) as between-subjects factor. Contrasts were Bonferroni-Holm corrected across the five calculated models (standard model, three CTQ-subscale models, and interpersonal trauma model). The confusion data were overdispersed like the response accuracy data, and dispersion parameters were estimated separately for each group as described above.

In order to analyse differences in the confusion of an emotional facial expression with a neutral one between

groups accounting for overdispersion, again beta-binomial generalized linear models were calculated, one for each (non-neutral) emotional expression. These analyses were Bonferroni-Holm corrected across the five alternative models as well. Odds ratios (exponentiations of the beta coefficients from the regression model termed ' $exp(b)$ ') were calculated as effect size measures and are reported with their confidence intervals as above.

To estimate the achieved statistical power of each calculated model, we determined the proportion of significant results when the same model was fitted on a pool of 200 randomly generated data sets simulating the observed distribution function, group difference and overdispersion (where applicable).

In addition, we tested whether possible group differences in confusing neutral expressions with expressions of negative emotions were affected by group differences in learning due to repeatedly showing negative expressions over the course of the experiment. In a first step, trials of positive, negative and neutral expressions were subdivided in three blocks according to their presentation in the first, second or final third of all trials (each third corresponding to 60 out of 180 total trials for negative expressions, to 20 out of 60 total trials for positive expressions, and to 10 out of 30 total trials for neutral expressions). Learning effects were then analysed in SPSS using generalized estimating equations (binomial distribution with logit link, compound symmetric working correlation matrix type, robust estimators to account for the overdispersion), including the between-subject factor group (PTSD, TC, HC), the within-subject factors valence ('positive', 'negative', and 'neutral') and block (1st, 2nd, 3rd), and the dependent variable 'number of correct responses'. The total number of trials for each emotional expression in each block served as reference. Significant effects were explored using pairwise group comparisons. Bonferroni-Holm corrections were applied and odds ratios were calculated as effect size measure. As will be reported in detail below, this analysis revealed improvements in recognizing negative emotions across the experiment. Therefore, in a second step, to test for an association between this improvement and the confusion of neutral with negative expressions, the difference between the percentages of correctly identified negative expressions of the last and the first block was Spearman correlated with the number of correct responses in recognizing neutral expressions (separately for all participants and for each analysed group).

3. Results

The number of neutral trials (out of 30) mistaken as an emotional expression ranged from $M = 0.09$ $SD = 0.80$ for disgust to $M = 2.37$ $SD = 2.97$ for sadness. The number of emotional trials (out of 270) mistaken as neutral ranged from $M = 0.49$ $SD = 0.90$ for pride to $M = 5.58$ $SD = 4.89$ for contempt. Accuracy of the

recognition of neutral expressions was neither correlated with the accuracy of the recognition of positive emotional expression ($r_s(116) = 0.091, p = .329$) nor with the recognition of negative emotional expressions in the whole sample ($r_s(116) = -0.084, p = .370$).

3.1. Groups based on PTSD diagnosis and model fit comparisons

No influence of the diagnostic group on correctly detecting neutral expressions was found (see Table 2). There were also no differences between diagnostic groups in the analysed confusion patterns (see Table 3).

The comparison of model fits revealed that four alternative models fit the data better than the model based on diagnostic groups (Table 2): three models based on CTQ subscales (for the subscales for sexual abuse, emotional abuse, and for physical neglect) and the model based on interpersonal trauma. Of these four, only the model based on the CTQ sexual abuse subscale (reported in detail below, see chapter 3.2) remained significant after Bonferroni-Holm correction.

The recognition accuracy of neutral facial expressions was neither influenced by the number of

experienced trauma types, by 'interpersonal trauma', by state dissociation, nor by alexithymia. Except for 'interpersonal trauma', all of these analyses had a poorer fit than the standard model. There was no difference in confusion patterns between individuals with interpersonal trauma vs. no trauma or non-interpersonal trauma (see Table 3).

Diagnostic groups did not differ in mistaking emotional expressions as neutral (see appendix, Table A2).

3.2. Groups based on child maltreatment

Participants with high scores on the CTQ subscale 'sexual abuse' performed more poorly in the recognition of neutral expressions than participants with low scores (see Table 2).

Higher levels of childhood sexual and emotional abuse, and physical neglect were associated with increased odds for interpreting neutral facial expressions as contempt and (for sexual abuse and physical neglect) for interpreting neutral facial expressions as anger (see Table 3 and Figure 1).

BDI sum score within the high CTQ groups for sexual abuse, physical neglect and emotional abuse did not correlate with the interpretation of neutral

Table 2. Recognition accuracy of neutral expressions: Model fit (AIC) and effect statistics (Z score, P-values, odds ratios) for models with alternate grouping variables (GVs).

DV	GV	AIC	Z	P	P_H	1- β	OR, 95% CI
ACC	Diagnostic group	635.30	-1.42	0.155	1.000	0.35	0.71 [0.44, 1.14]
	CTQ sexual abuse	624.20	-3.39	0.001	0.010*	0.90	0.46 [0.29, 0.72]
	CTQ physical neglect	630.79	-2.57	0.010	0.090	0.69	0.56 [0.36, 0.87]
	CTQ emotional abuse	632.67	-2.17	0.030	0.240	0.55	0.61 [0.39, 0.95]
	Interpersonal	635.08	-1.21	0.225	1.000	0.18	0.76 [0.48, 1.19]
	CTQ physical abuse	635.34	-1.43	0.153	1.000	0.34	0.72 [0.46, 1.13]
	CTQ emotional neglect	635.97	-1.18	0.237	1.000	0.28	0.75 [0.47, 1.21]
	NOET	636.02	0.90	0.368	1.000	0.12	1.25 [0.77, 2.05]
	TAS	636.48	-1.17	0.242	1.000	0.27	0.76 [0.47, 1.21]
	RSDI	636.64	0.73	0.464	1.000	0.09	1.18 [0.76, 1.85]
DV	GV	AIC	T	P	P_H	1- β	D, 95% CI
RT	Diagnostic group	1711.03	0.86	0.392	1.000	0.15	0.18 [-0.22, 0.57]
	CTQ emotional neglect	1702.28	2.66	0.009	0.089	0.84	0.48 [0.10, 0.85]
	CTQ emotional abuse	1705.74	2.15	0.034	0.305	0.69	0.38 [0.01, 0.75]
	CTQ physical neglect	1705.76	2.13	0.035	0.305	0.76	0.39 [0.01, 0.76]
	CTQ physical abuse	1706.79	1.95	0.054	0.376	0.69	0.36 [-0.02, 0.72]
	CTQ sexual abuse	1707.27	1.78	0.078	0.470	0.20	0.36 [-0.03, 0.74]
	TAS	1708.59	-1.57	0.119	0.596	0.48	-0.29 [-0.66, 0.08]
	RSDI	1709.37	-1.40	0.165	0.659	0.38	-0.27 [-0.67, 0.13]
	NOET	1711.03	0.86	0.391	1.000	0.16	0.18 [-0.22, 0.58]
	interpersonal	1711.37	0.72	0.471	1.000	0.12	0.14 [-0.24, 0.52]

DV = dependent variable

ACC = response accuracy

RT = reaction time

Bold = better model fit than diagnostic model

GV = Grouping variable

CQT = Childhood Trauma Questionnaire

NOET = number of traumatic events

TAS-20 = Toronto Alexithymia Scale

RSDI = Responses to Script-Driven Imagery Scale

P = Probability under H_0

P_H = Bonferroni-holm corrected probability under H_0

* = $P_H < .050$

OR = Odds ratio

D = Cohen's d

CI = confidence interval

1- β = statistical power

Odds ratios/Cohen's ds refer to the comparisons between the groups with the highest and lowest traumatic burden, alexithymia or dissociation (e.g. PTSD vs HC, high CTQ vs. low CTQ, high alexithymia vs. low alexithymia, high dissociation vs. low dissociation)

Table 3. Confusions of neutral with other emotional expressions: Effect statistics (Z score, P-values, odds ratios) for the standard model and models with better model fit.

Stimulus	Response	GV	Z	P	P_H	1- β	OR, 95% CI
Neutral	Anger	Diagnostic group	1.47	0.142	0.284	0.32	1.97 [0.80, 4.89]
		CTQ sexual abuse	3.07	0.002	0.011*	0.83	3.37 [1.55, 7.33]
		CTQ physical neglect	2.94	0.003	0.013*	0.85	3.44 [1.51, 7.85]
		CTQ emotional abuse	1.79	0.073	0.219	0.44	2.13 [0.93, 4.85]
		interpersonal	-1.05	0.295	0.295	0.18	0.57 [0.20, 1.63]
Neutral	Contempt	Diagnostic group	1.69	0.091	0.183	0.42	2.36 [0.87, 6.42]
		CTQ sexual abuse	2.97	0.003	0.015*	0.86	2.97 [1.45, 6.09]
		CTQ physical neglect	2.77	0.006	0.022*	0.78	2.76 [1.35, 5.66]
		CTQ emotional abuse	2.46	0.014	0.042*	0.74	2.51 [1.21, 5.23]
		interpersonal	0.58	0.563	0.563	0.10	1.35 [0.49, 3.72]
Neutral	Fear	Diagnostic group	-0.47	0.639	1.000	0.09	0.82 [0.35, 1.90]
		CTQ sexual abuse	1.32	0.185	0.742	0.34	1.65 [0.79, 3.47]
		CTQ physical neglect	0.24	0.812	1.000	0.07	1.10 [0.52, 2.32]
		CTQ emotional abuse	0.71	0.478	1.000	0.11	1.30 [0.63, 2.70]
		interpersonal	-1.84	0.066	0.331	0.40	0.40 [0.15, 1.06]
Neutral	Sadness	Diagnostic group	0.75	0.456	0.912	0.10	1.35 [0.62, 2.94]
		CTQ sexual abuse	1.67	0.095	0.474	0.46	1.62 [0.92, 2.84]
		CTQ physical neglect	1.35	0.178	0.534	0.28	1.49 [0.83, 2.67]
		CTQ emotional abuse	1.58	0.113	0.474	0.34	1.59 [0.90, 2.82]
		interpersonal	0.74	0.46	0.912	0.11	1.33 [0.62, 2.84]
Neutral	Shame	Diagnostic group	-2.22	0.026	0.131	0.55	0.33 [0.12, 0.88]
		CTQ sexual abuse	0.42	0.673	0.958	0.08	1.21 [0.50, 2.88]
		CTQ physical neglect	-1.78	0.075	0.224	0.43	0.47 [0.21, 1.08]
		CTQ emotional abuse	-1.99	0.046	0.186	0.48	0.44 [0.20, 0.99]
		interpersonal	-0.71	0.479	0.958	0.06	0.73 [0.30, 1.76]
Neutral	Disgust	Diagnostic group	0.08	0.935	1.000	0.00	1.07 [0.22, 5.31]
		CTQ sexual abuse	1.46	0.143	0.572	0.18	2.96 [0.69, 9.63]
		CTQ physical neglect	1.86	0.063	0.317	0.25	4.73 [0.92, 0.00]
		CTQ emotional abuse	0.31	0.757	1.000	0.08	1.25 [0.31, 5.01]
		interpersonal	-1.27	0.205	0.616	0.08	0.24 [0.03, 2.17]
Neutral	Surprise	Diagnostic group	-0.33	0.741	1.000	0.02	0.82 [0.25, 2.67]
		CTQ sexual abuse	1.03	0.303	1.000	0.19	1.79 [0.59, 5.41]
		CTQ physical neglect	0.7	0.485	1.000	0.10	1.49 [0.48, 4.60]
		CTQ emotional abuse	-0.39	0.694	1.000	0.06	0.80 [0.26, 2.46]
		interpersonal	-0.64	0.524	1.000	0.08	0.54 [0.08, 3.60]
Neutral	Joy	Diagnostic group	0.77	0.443	1.000	0.07	1.54 [0.51, 4.59]
		CTQ sexual abuse	-0.4	0.689	1.000	0.05	0.80 [0.26, 2.41]
		CTQ physical neglect	-0.58	0.563	1.000	0.10	0.73 [0.24, 2.15]
		CTQ emotional abuse	-1.23	0.22	1.000	0.21	0.53 [0.19, 1.47]
		interpersonal	-0.78	0.438	1.000	0.14	0.53 [0.11, 2.62]
Neutral	Pride	Diagnostic group	-1.04	0.301	1.000	0.06	0.41 [0.07, 2.23]
		CTQ sexual abuse	0.19	0.847	1.000	0.17	1.15 [0.29, 4.60]
		CTQ physical neglect	-0.4	0.687	1.000	0.01	0.78 [0.23, 2.67]
		CTQ emotional abuse	1.67	0.094	0.471	0.13	3.14 [0.82, 9.02]
		interpersonal	-0.6	0.549	1.000	0.05	0.63 [0.14, 2.83]

GV = Grouping variable

CQT = Childhood Trauma Questionnaire

P = Probability under H_0 P_H = Bonferroni-holm corrected probability under H_0 * $p < .05$ 1- β = statistical power

OR = Odds ratio

CI = confidence interval

Effect statistics and Odds ratios refer to the comparisons between the groups with the highest and lowest traumatic burden (e.g. PTSD vs HC, high CTQ vs. low CTQ)

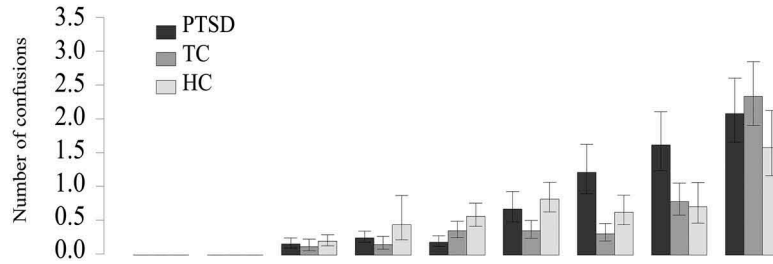
expressions as neutral (absolute $r_s's(41) < .092$, Bonferroni-Holm corrected $p's = 1.0$), as contempt (absolute $r_s's(41) < .150$, Bonferroni-Holm corrected $p's > .876$), or as anger (absolute $r_s's(41) < .312$, Bonferroni-Holm corrected $p's > .861$). No influence of CTQ was found on mistaking emotional expressions as neutral ($p's > .084$, see appendix, Table A2).

3.3. Learning effects

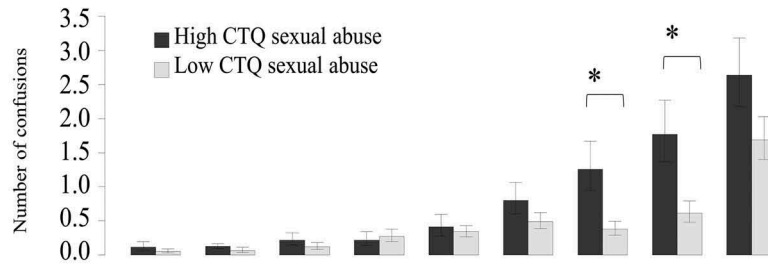
The analysis for learning effects revealed that there was a general improvement in response accuracy across the blocks of the experiment (main effect

'block': Wald $X^2(2) = 19.13$, $p < .001$). There was no specific advantage of one valence of expressions ('valence' x 'block': Wald $X^2(4) = 8.37$, $p = .079$), one group ('valence' x 'group': Wald $X^2(4) = 8.66$, $p = .070$) or one valence in a specific group ('valence' x 'block' x 'group': Wald $X^2(8) = 5.30$, $p = .725$). Improvement in correct identification of *negative* expressions from block 1 to block 3 was unrelated to the recognition of neutral facial expressions as neutral across the three blocks, both for the whole sample ($r_s(116) = -.118$, $p = .211$), and for each of the CTQ-based groups separately (absolute $r_s's < .278$, Holm-corrected $p's > .114$).

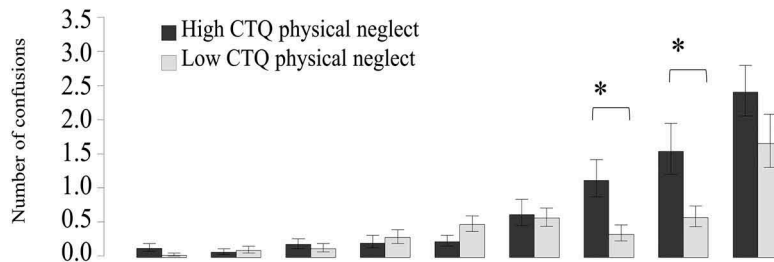
Panel 1: Neutral expressions mistaken as emotional by diagnostic group



Panel 2: Neutral expressions mistaken as emotional by CTQ sexual abuse



Panel 3: Neutral expressions mistaken as emotional by CTQ physical neglect



Panel 4: Neutral expressions mistaken as emotional by CTQ emotional abuse

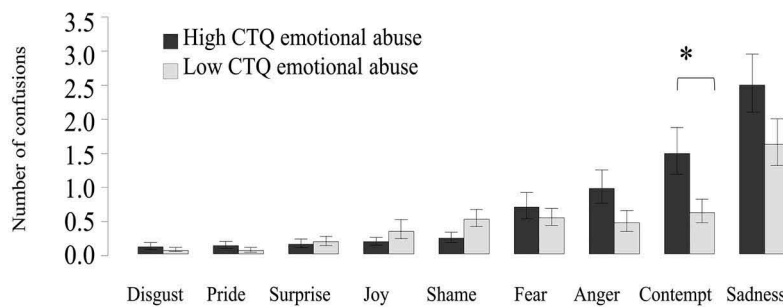


Figure 1. Confusions in diagnostic groups and for groups based on CTQ-subscale sexual abuse, physical neglect, and emotional abuse. Error bars indicate standard errors (calculated on link level and transformed back to response level). Neutral expressions were mistaken as pride or disgust in so few cases that models could not be fitted.

* $P_H < .050$

3.4. Reaction times

Groups did not differ regarding reaction times for correct responses in the standard model. All alternative models (except for the NOET-, and the interpersonal trauma-model) showed an improved model fit. Models based on the CTQ subscales emotional neglect, emotional abuse and physical neglect revealed increased reaction times of participants with higher traumatic

burden, but none of these effects survived the Bonferroni-Holm correction (see Table 2).

4. Discussion

The present study assessed recognition and interpretations of neutral facial expressions in individuals with PTSD compared to traumatized and non-traumatized

healthy controls. Against our hypothesis, PTSD participants did not perform differently from controls in the recognition of neutral expressions. They also did not show different confusion patterns than healthy controls. Instead, individuals with high levels of childhood sexual abuse performed worse in the recognition of neutral facial expressions than individuals with low levels of sexual abuse. Furthermore, individuals with high versus low levels of childhood experiences of sexual abuse, physical neglect and emotional abuse interpreted neutral expressions more frequently as contempt and (for sexual abuse and physical neglect) more frequently as anger. Compared to all other models based on different variables (e.g. alexithymia, NOET) or based on diagnostic groups, the model based on childhood sexual abuse had the best model fit, which suggests that misinterpretations of neutral expressions are best explained by experiences of childhood sexual abuse. Groups did not differ in RTs of correctly identified neutral expressions.

4.1. Negative interpretation of neutral expressions and child maltreatment

Our results suggest that the experience of child maltreatment, particularly childhood sexual abuse, but not PTSD is associated with difficulties in the recognition of neutral expressions and with negative interpretations of neutral facial expressions. Learning effects on negative emotional expressions over the course of the emotion recognition paradigm do not seem to explain negative interpretations of neutral expressions in individuals with high levels of child maltreatment, as these variables were unrelated. Furthermore, there were no group differences in interpreting *emotional* expressions as neutral. Thus, interpretations of neutral expressions as expressions of negative emotion do not seem to be a function of a general tendency to misinterpret facial expressions.

To date, only one published study has assessed the interpretation of neutral facial expressions in individuals with PTSD (Nazarov et al., 2014). This study found no differences between individuals with PTSD and healthy controls. On the one hand, our findings align with this study and confirm its results in a different sample and by means of whole face stimuli that are close to real life, rather than showing the eye region of the face only. On the other hand, our null finding is surprising, given that other clinical populations with a high prevalence of child maltreatment tend to interpret neutral facial expressions as negative (Battle et al., 2004; Daros et al., 2013; Meehan et al., 2017; Mitchell et al., 2014; Schlumpf et al., 2013; Wingenfeld et al., 2011). According to our own and other (Catalan et al., 2018) findings, child maltreatment might be a more important predictor of this

negativity bias than the presence of mental disorders like PTSD or borderline personality disorder.

It is interesting that interpretations of neutral expressions as emotional expressions in individuals with child maltreatment were restricted to negative facial expressions (anger and contempt) but were not found for positive facial expressions (joy or pride). This is in line with Catalan et al. (2018), who found that child maltreatment in adults was associated with the attribution of negative emotions (anger and fear) to neutral facial expressions and aligns further with research on individuals with BPD who are hypervigilant towards anger-related cues, have difficulties differentiating angry from neutral faces, and tend to interpret neutral expressions as expressions of anger (Daros et al., 2013; Domes et al., 2008; Donegan et al., 2003; Mitchell et al., 2014).

There is some evidence that neutral facial expressions can trigger traumatic memories in individuals with dissociative identity disorder – a condition associated with severe child maltreatment (Schlumpf et al., 2013). In an fMRI study in individuals with dissociative identity disorder, masked neutral faces activated brain processes related to arousal/vigilance and specific brain areas that have been linked to re-experiencing of traumatic events; this response was even more pronounced than responses of individuals with dissociative identity disorder to masked angry faces (Schlumpf et al., 2013). As suggested by anecdotal evidence, traumatic childhood experiences like sexual or physical abuse can be preceded, accompanied or followed by neutral facial expressions by the perpetrator. Individuals with these types of adverse childhood experiences may thus have learned to not trust the seemingly calmness of neutral expressions, due to expectations that neutral situations are followed by aversive experiences (Schlumpf et al., 2013). Due to hypervigilance towards threat-related cues, the threshold to detect anger (on a continuum from positive to negative facial expressions) might furthermore be lower in individuals with child maltreatment. Indeed, maltreated children showed attentional preference towards angry facial expressions and a higher sensitivity towards detecting anger (Gibb, Schofield, & Coles, 2009).

Different types of child maltreatment might shape emotion recognition abilities in different ways (Pollak, 2003). In our study, it was childhood sexual abuse which best explained misinterpretations of neutral facial expressions and which was associated with difficulties in the recognition of neutral expressions. Several authors describe the detrimental impact of childhood sexual abuse on psychological, neurocognitive and neurobiological functioning [e.g. De Bellis, Spratt, and Hooper (2011)]. A recent representative epidemiologic study in Germany found that the highest prevalence of complex PTSD, which is

characterized by severe impairments in affect dysregulation, negative beliefs about oneself and problems in relationships in addition to the typical symptoms of PTSD (World Health Organization, 2015), is found in individuals with childhood sexual abuse and rape (Maercker, Hecker, Augsburger, & Kliem, 2018). Together with the association between sexual trauma and poorer performance on social cognition found in individuals with BPD (Preißler, Dziobek, Ritter, Heekeren, & Roepke, 2010), this suggests that childhood sexual abuse may have a particularly pronounced, detrimental impact not only on affected individuals' cognitive and emotional development but also on social skills, including the ability to correctly identify facial expressions.

In sum, negative interpretations of neutral facial expressions in individuals with a history of child maltreatment may reflect learning processes taking place in neglectful and/or abusive environments. While these learning processes may be adaptive in the initial environment, e.g. by alerting children to potentially harmful situations, they may have negative consequences on the building and maintenance of interpersonal relationships in adulthood.

4.2. Alexithymia, number of trauma types, interpersonal trauma, and dissociation

NOET, interpersonal trauma, alexithymia, and state dissociation seem to play a less relevant (and non-significant) role than childhood sexual abuse for the recognition of neutral facial expressions. This is in contrast to the recognition of *emotional* facial expressions, for which, according to our previous research, NOET, state dissociation, and alexithymia appeared to play a more important role than PTSD diagnosis itself (Passardi, 2018; Passardi et al., 2019). However, our results align with neurobiological studies demonstrating that facial emotion recognition and recognition of neutral facial expressions involve different neuronal structures (Fusar-Poli et al., 2009; Jehna et al., 2011) and with our finding that accuracy for neutral facial expressions was neither correlated with accuracy for positive nor for negative facial expressions. Only few previous studies have analysed the association between alexithymia and recognition of neutral expressions. The results of these studies are inconclusive. In line with the present and our previous (Frewen et al., 2008) findings, evidence more strongly suggests that internal representations of emotional rather than neutral expressions are impaired in alexithymic individuals (Grynberg et al., 2012). Similarly, state dissociation and higher numbers of experienced trauma types seem to disturb the processing of emotional facial expressions (Passardi et al., 2018) but not of neutral expressions. Finally, our results suggest that it is not the 'interpersonal-

trauma-aspect' of child maltreatment but specific types of child maltreatment, which are associated with misinterpretations of neutral expressions.

4.3. Limitations and conclusions

A major limitation is the fact that this manuscript is based on the recognition of 30 neutral stimuli that were presented as part of an emotion recognition paradigm that included a total of 300 (negative, positive and neutral) facial expression stimuli, which may have affected interpretation of neutral stimuli. However, we found that recognition of neutral expressions did not change due to learning effects for emotional expressions over the course of the experiment. Another limitation of this study is the difference between the PTSD and TC group regarding the distribution of trauma types, with more type II trauma reported by the PTSD group. Risk for PTSD is higher after type II trauma (Brewin, Andrews, & Valentine, 2000), making it difficult to find comparable control groups when assessing samples with mixed trauma types. Third, our experimental stimuli are closer to real-life interactions than static (black and white) images or images restricted to the eye region of the face. Nevertheless, future research should assess recognition of neutral expressions as they occur in interactive processes in and – ultimately – outside the laboratory, to enhance ecological validity. Fourth, while for the majority of significant effects, estimations of achieved power reached an at least satisfying level, power estimations for two of the significant findings (more confusions of neutral expressions with contempt in the high vs. low physical neglect and emotional abuse groups) were slightly below the desired threshold of .8, pointing to a risk of false positives. Finally, our findings regarding CTQ subgroups are based on a sample comprising individuals with and without PTSD. Future research should attempt to replicate our findings in a sample that is characterized by the presence (and absence) of child maltreatment.

Overall, our research shows that not PTSD, but specific types of (childhood) traumatic experiences are associated with difficulties in the interpretation of neutral expressions. It is important to identify individuals prone to misinterpret neutral expressions as negative because they will likely feel uncomfortable in social interactions, including psychotherapeutic interactions, and, potentially, show behavioural responses to neutral expressions that may cause interactive and thus relationship problems that are common in traumatized individuals (Cloitre, Scarvalone, & Difede, 1997). There is evidence that specific facial expressions of therapists are associated with therapeutic relationship quality as perceived by the patient (Sharpley, Jeffrey, & McMahan, 2006). If the

negative interpretation bias we found extends to real-life situations, future research should explore if the therapeutic relationship with traumatized individuals can be improved by increasing therapists' awareness of their facial expressions and of their patients' responses to and interpretations of nonverbal signals of therapists and other interaction partners. Additionally, future research should explore whether the deficits we found extend to other, non-verbal communication channels such as the tone of the voice, as found in individuals with BPD (Niedtfeld et al., 2017). There is evidence from individuals with depressive and social anxiety symptoms that emotion recognition training (e.g. changing the threshold of perceiving a facial expression as angry) can reduce negativity biases (Penton-Voak et al., 2018; Rawdon et al., 2018). Further research might also explore if such training might counteract a negativity bias for neutral expressions in individuals with a history of childhood (sexual and emotional) abuse, and (physical) neglect. Further elaborating on our results may contribute to a better understanding of emotional processing, including the recognition of neutral facial expressions, in (childhood) traumatized individuals, potentially helping them to create more satisfying social interactions.

Disclosure statement

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Appendix

Table A1. Group sizes for model fit comparisons.

GV	Group descriptions	N1	N2
Diagnostic group	HC/TC vs. PTSD	77	37
CTQ sexual abuse	low vs. high	73	41
CTQ physical neglect	low vs. high	62	52
CTQ emotional abuse interpersonal	low vs. high	57	57
	no trauma or non-interpersonal trauma vs. interpersonal trauma	73	41
CTQ physical abuse	low vs. high	62	52
CTQ emotional neglect	low vs. high	55	59
NOET	0,1 or 2 vs. 3 or more	79	35
TAS-20	low vs. high	55	59
RSDI	low vs. high	80	34

Bold = better model fit than diagnostic model

GV = Grouping variable

CQT = Childhood Trauma Questionnaire

NOET = number of traumatic events

TAS-20 = Toronto Alexithymia Scale

RSDI = Responses to Script-Driven Imagery Scale

Table A2. Confusions of other emotional expressions with neutral: Effect Statistics (Z score, P-values, odds ratios) for the Standard Model and Models with better Model Fit.

Stimulus	Response	GV	Z	P	P _H	1-β	OR [95% CI]
Anger	Neutral	Diagnostic group	-0.05	0.962	1.000	0.07	0.99 [0.58, 1.69]
		CTQ sexual abuse	-0.70	0.485	1.000	0.14	0.84 [0.51, 1.37]
		CTQ physical neglect	0.09	0.927	1.000	0.04	1.02 [0.65, 1.59]
		CTQ emotional abuse	-1.46	0.145	0.723	0.29	0.73 [0.48, 1.12]
		interpersonal	0.57	0.569	1.000	0.08	1.14 [0.72, 1.81]
Contempt	Neutral	Diagnostic group	-1.04	0.300	0.300	0.17	0.78 [0.49, 1.25]
		CTQ sexual abuse	-1.88	0.060	0.238	0.45	0.70 [0.48, 1.01]
		CTQ physical neglect	-1.59	0.113	0.238	0.29	0.75 [0.53, 1.07]
		CTQ emotional abuse	-2.16	0.030	0.152	0.55	0.68 [0.48, 0.96]
		interpersonal	-1.80	0.071	0.238	0.36	0.67 [0.43, 1.04]
Fear	Neutral	Diagnostic group	1.41	0.158	0.633	0.27	1.86 [0.79, 4.38]
		CTQ sexual abuse	2.39	0.017	0.085	0.68	2.36 [1.17, 4.78]
		CTQ physical neglect	-0.23	0.821	1.000	0.07	0.91 [0.42, 1.99]
		CTQ emotional abuse	0.57	0.566	1.000	0.10	1.23 [0.60, 2.53]
		interpersonal	1.21	0.228	0.683	0.24	1.76 [0.70, 4.40]
Sadness	Neutral	Diagnostic group	0.15	0.881	1.000	0.04	1.05 [0.57, 1.93]
		CTQ sexual abuse	-0.13	0.895	1.000	0.06	0.96 [0.56, 1.66]
		CTQ physical neglect	-0.55	0.581	1.000	0.08	0.86 [0.52, 1.45]
		CTQ emotional abuse	-0.87	0.384	1.000	0.17	0.80 [0.48, 1.32]
		interpersonal	1.18	0.237	1.000	0.22	1.42 [0.79, 2.55]
Shame	Neutral	Diagnostic group	0.25	0.800	1.000	0.08	1.06 [0.68, 1.64]
		CTQ sexual abuse	-0.60	0.549	1.000	0.07	0.88 [0.58, 1.34]
		CTQ physical neglect	-1.23	0.217	1.000	0.22	0.79 [0.55, 1.15]
		CTQ emotional abuse	-0.42	0.675	1.000	0.10	0.92 [0.64, 1.33]
		interpersonal	-0.22	0.823	1.000	0.09	0.95 [0.62, 1.45]
Disgust	Neutral	Diagnostic group	-0.01	0.996	1.000	0.02	1.00 [0.59, 1.68]
		CTQ sexual abuse	0.23	0.815	1.000	0.09	1.06 [0.64, 1.76]
		CTQ physical neglect	0.31	0.754	1.000	0.07	1.07 [0.69, 1.68]
		CTQ emotional abuse	-0.77	0.440	1.000	0.15	0.85 [0.55, 1.29]
		interpersonal	0.04	0.969	1.000	0.06	1.01 [0.60, 1.71]
Surprise	Neutral	Diagnostic group	1.34	0.180	0.540	0.35	1.68 [0.79, 3.58]
		CTQ sexual abuse	2.25	0.025	0.123	0.61	2.09 [1.10, 3.98]
		CTQ physical neglect	0.52	0.604	1.000	0.07	1.20 [0.60, 2.38]
		CTQ emotional abuse	1.88	0.060	0.241	0.53	1.82 [0.97, 3.40]
		interpersonal	0.48	0.632	1.000	0.07	1.23 [0.53, 2.82]
Joy	Neutral	Diagnostic group	1.64	0.101	0.503	0.40	1.63 [0.91, 2.90]
		CTQ sexual abuse	1.63	0.102	0.503	0.36	1.48 [0.93, 2.36]
		CTQ physical neglect	0.90	0.370	0.971	0.15	1.23 [0.78, 1.96]
		CTQ emotional abuse	0.74	0.462	0.971	0.11	1.19 [0.75, 1.86]
		interpersonal	0.99	0.324	0.971	0.17	1.34 [0.75, 2.39]
Pride	Neutral	Diagnostic group	1.02	0.308	1.000	0.21	1.49 [0.69, 3.22]
		CTQ sexual abuse	0.77	0.443	1.000	0.15	1.33 [0.64, 2.76]
		CTQ physical neglect	1.17	0.242	1.000	0.25	1.50 [0.76, 2.96]
		CTQ emotional abuse	1.10	0.270	1.000	0.22	1.46 [0.75, 2.86]
		interpersonal	-1.25	0.211	1.000	0.19	0.58 [0.25, 1.36]

GV = Grouping variable

CQT = Childhood Trauma Questionnaire

P = Probability under H₀

P_H = Bonferroni-holm corrected probability under H₀

*p < .05

1-β = statistical power

OR = Odds ratio

CI = confidence interval

Effect statistics and Odds ratios refer to the comparisons between the groups with the highest and lowest traumatic burden (e.g. PTSD vs HC, high CTQ vs. low CTQ)