Early ERP components to emotional facial expressions in young adult victims of childhood maltreatment

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ARTICLE INFO

ABSTRACT

The ability to appropriately recognize the facial expression of emotions is essential for the development of adaptive functioning. Studies suggest that maltreated children are hypersensitive to expression of anger. However, the neural mechanism of emotional face processing in young adults with a history of childhood maltreatment has yet to be explored. To explore whether the history of childhood maltreatment has a potential relationship with processing of emotional facial expressions, the present study used event-related potentials in investigating the early ERP components (P100 and N170) to the processing of emotional (angry, fearful, disgusted, and happy) faces in young adult victims of childhood maltreatment. Seventeen young adults with a history of childhood maltreatment and seventeen age and gender-matched non-maltreated participants performed a modified dot-probe task, using emotional faces paired with neutral faces. Results revealed no significant differences between maltreated group and non-maltreated group in P100 amplitude, but the N170 amplitude in the maltreated group was larger than non-maltreated group when processing angry, fearful, and happy faces. As such, this study provides biological evidence of altered neural processing of emotional facial expressions in young adults with a history of childhood maltreatment.

1. Introduction

Childhood maltreatment is a type of trauma occurring during dynamic neurobiological development (Twardosz and Lutzker, 2010). It is typically defined as harm, potential harm, or the threat of harm resulting either directly from caregivers or indirectly via their neglect. Mental health research has established that childhood maltreatment is related to a greater lifetime risk of psychiatric disorders, including depression (Heim et al., 2008; Nanni et al., 2012), bipolar disorder (Agnew-Blais and Danese, 2016), schizophrenia (Read et al., 2005), and posttraumatic stress disorder (Yehuda et al., 2001). Even prior to the onset of symptoms, children who have been maltreated tend to display atypical patterns in emotional-state recognition, expression, and regulation (Camras et al., 1990, 1996; Pollak et al., 2000).

The ability to appropriately recognize the facial expression of emotions is vital for almost every aspect of social interaction and essential for developing adaptive functioning (Sroufe, 1996). Correct

categorization of facial expressions relies upon knowledge comprising the scope of emotional categories and their boundaries, that is, the identification of ambiguous facial expressions; this knowledge, in turn, is a product of experience and learned expectations (Pollak and Sinha, 2002), including the frequency of exposure to specific emotions (Beale and Keil, 1995). Thus, a prerequisite for the development of appropriate emotion-processing abilities seems to be appropriate day-to-day emotional experiences in social interactions.

Theorists seem to agree that negative childhood experiences, childhood maltreatment, in particular, play significant roles in developing experience-based specific biases in processing information (Cicchetti et al., 2000; Pollak and Tolley-Schell, 2003; Rose and Abramson, 1992). From the point of view of the child, this may be adaptive because increased sensitivity to anger signals, for example, may facilitate avoiding maltreatment (Cicchetti et al., 2000; Pollak and Tolley-Schell, 2003). Specifically, the rapid perception of even small signals of anger may cause a child to leave a potentially violent

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situation (Gibb et al., 2009).

Compared to their peers who have not been maltreated, maltreated children tend to have atypical experiences or perceptions of emotional cues. They usually perceive fewer cues of positive emotions (Bugental et al., 1990) and perceive more cues of negative emotions (Herrenkohl et al., 1991). Studies investigating associations between these phenomena and parenting suggest that abusive parents, on average, exhibit less positive affect and more negative affect than parents who are not abusive (Bugental et al., 1990; Kavanagh et al., 1988). Parents who maltreat their children are often isolated, and they also tend to isolate their children. To varying degrees, this prevents interaction with other adults and, thus, limits the children's exposure to non-parental models of emotional communication (Salzinger et al., 1992). Furthermore, children who are brought up in emotionally inconsistent or harsh environments exhibit difficulties in predicting the consequences of parental behavior, which, in turn, may facilitate the development of emotion-processing deficits (Dadds and Salmon, 2003). In general, there seems no doubt that childhood abuse disrupts the course of normal emotional development.

Consistent with the above review, behavioral results and results from event-related potentials (ERPs) suggest that children who have been maltreated have difficulty disengaging their attentions from angry faces (Pollak and Tolley-Schell, 2003). Their recognition of emotions is less accurate than that of non-maltreated children, and they more frequently categorize emotions as anger or sadness (Camras et al., 1988; Pollak et al., 2000). A greater P3b was found in response to angry faces in school-aged maltreated children, indicating hyper-responsivity to angry faces compared with non-maltreated peers (Pollak et al., 2001). Cicchetti and Curtis examined ERPs to faces displaying different affective states in a sample of maltreated children between 30 and 42 months of age and found exaggerated responses to angry facial affect (Cicchetti and Curtis, 2005; Curtis and Cicchetti, 2011).

Other studies suggest that physically maltreated and aggressive children are characterized by early-stage information-processing biases (Dodge et al., 1997; Dodge et al., 1990; Weiss et al., 1992). For this group, displays of anger seem to constitute salient threat cues. Consistent with this, their perceptual boundaries for categorizing anger seem to be broader (Pollak and Kistler, 2002), and their accuracy to identify anger using only sparse perceptual information seems to be better (Pollak and Sinha, 2002) compared to non-maltreated peers. In some attention research, they seem to allocate relatively more resources for processing facial expressions of anger (Pollak et al., 1997), and exhibit a larger P300 amplitude to angry faces than the control group does (Pollak and Tolley-Schell, 2003). Maltreated children have a tendency to be less accurate in global facial tasks, and they are more reactive, show response bias, and have greater electrophysiological activity to anger. Taken together, these results indicate that maltreated children have a general abnormality in the processing of emotional facial expressions. Nevertheless, the question remains whether these deficits continue into adulthood.

Assuming that the information-processing biases caused by childhood maltreatment are relatively stable, young adults who have been maltreated in childhood should still exhibit attentional biases for the expression of anger. A recent study found adults who were maltreated in childhood were less accurate in overall emotion categorization than matched controls, and exhibited slower processing of both affect-positive and neutral pictures (Young and Widom, 2014). It should be noted, however, that different studies of these attentional biases to emotional faces have yielded conflicting results. For example, young adults exposed to maltreatment during childhood may show a bias towards threat cues (Gibb et al., 2009), or a bias toward happy faces (Fani et al., 2011).

Early ERP components occurring around 80–250 ms after stimulus onset, including the P100 and N170, are thought to reflect visual perceptual processing and structural encoding processing, respectively. The P100 is a positive-going component over occipital sites about 100 ms. It is thought to be an indicator of automatic early visual processing, including the processing of emotional faces. Curtis and Cicchetti found that younger maltreated children, who were tested at 42 months of age, had a larger P100 amplitude to angry faces than children who were not maltreated (Curtis and Cicchetti, 2011). That study provides evidence that maltreated children are hyper-reactive to angry faces, which has been demonstrated in several ERP studies (Pollak et al., 1997; Pollak et al., 2001). Moreover, an abnormal P100 elicited by emotional facial stimuli, which has been found in studies of major depressive disorder (Mingtian et al., 2011), bipolar disorder (Degabriele et al., 2011) and schizophrenia (Jetha et al., 2013), indicates that atypical neural processing of emotional faces occurs in clinical populations.

Another ERP component of early-stage processing of emotional facial expressions is the N170. The N170 ERP component, occurring 130–200 ms subsequent to stimulus onset for facial stimuli, is thought to index the structural encoding of faces, and it is most pronounced over posterior lateral brain areas (Bentin et al., 1999; Rossion et al., 1999). It has been found to be particularly sensitive to angry, fearful, and happy facial expressions (Hinojosa et al., 2015). According to electrophysiological and neuroimaging studies, its neural origins may be located in inferior temporal cortex, and particular emphasis has been put on the fusiform face area (Sadeh et al., 2010). Though the evidence of specific emotional sensitivity and asymmetries is inconsistent, N170 is considered a correlate of perceptual representation, indexing the integration of information on facial expression and identity at early stages of processing (Hinojosa et al., 2015). N170 anomalies have been found in patients with depression (Zhang et al., 2016) and social anxiety disorder (Hagemann et al., 2016), suggesting a negative processing bias or aberrant processing of facial identity or expression.

Based on the above review, the results of studies on the processing of emotional faces by young adult victims of childhood maltreatment are inconsistent. Thus, more evidence is needed to specify the cognitive mechanisms that are involved in stable emotional-information processing in this population. The current study aimed to examine early-stage processing of emotional facial expressions in young adults with a history of childhood maltreatment and a matched control group, using event-related potentials. This study used a modified version of the dot-probe task (MacLeod et al., 1986) to probe several facial-expression emotions (angry, fearful, disgusted, and happy faces) by pairing an emotional face with a neutral face during stimulus presentation.

The first question was whether a history of childhood maltreatment has a relationship with processing of emotional information. We hypothesized that young adults with a history of childhood maltreatment would be hyper-sensitive to emotional facial expressions compared to a non-maltreatment group, which would be demonstrated by greater P100 and N170 amplitudes and better performance on behavioral measures. If so, the next question was whether this hyper-sensitivity is valence-independent or valence-dependent. We hypothesized that increased P100 and N170 amplitudes would be specific to angry, fearful, and disgusted faces, but not happy faces.

2. Methods

2.1. Participants

A total of 1100 college students from the Hunan University of Chinese Medicine completed a screening questionnaire. The Childhood Trauma Questionnaire-Short Form (CTQ-SF) was used to screen 242 college students for moderate or extreme levels of childhood maltreatment (the CTQ-SF cut-off scores were: SA > 7; PA > 9; EA > 12; EN > 14; PN > 9). We randomly selected 30 college students from this sample to be participants, and assigned them to the maltreated group. Thirty matched participants without any history of childhood maltreatment were chosen for the control group (the CTQ-SF cut-off scores for the control group were: SA < 6; PA < 8; EA < 9; EN < 10; and PN
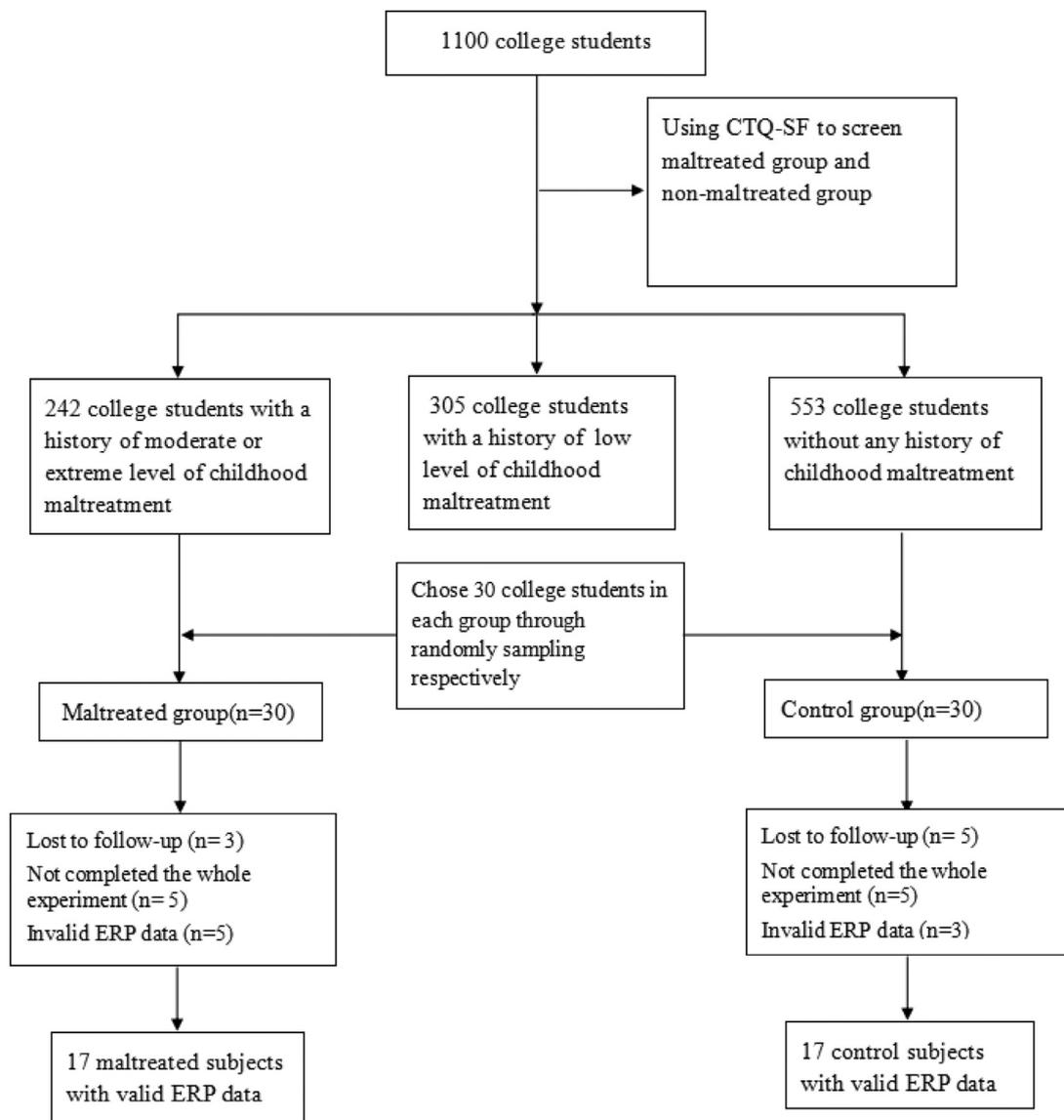
Fig. 1. Participants flow-chart.

Table 1
Demographic characteristics and clinical information.

| | Maltreated group | | Control group | | t/χ^2 | p value |
	Mean	Std Dev.	Mean	Std Dev.		
Age	21.35	0.70	21.59	1.18	0.708	0.484
Gender(M/F)	1/16		3/14		1.133	0.287
CTQ-SF scores						
Emotional abuse	8.82	3.17	6.35	1.46	2.923	0.006
Physical abuse	6.71	1.86	5.35	0.86	2.718	0.011
Sexual abuse	5.59	0.94	5.35	1.22	0.630	0.533
Emotional neglect	15.18	5.34	7.29	2.42	5.543	< 0.001
Physical neglect	11.00	2.76	6.35	1.46	6.139	< 0.001

corrected-to-normal vision. The Structured Clinical Interview for the DSM-IV (Diagnostic and Statistical Manual of Mental Disorders) was administered to exclude participants with schizophrenia, epilepsy, mood, anxiety, substance abuse or tic disorders. Table 1 provides detailed participant information.

All the participants provided their written informed consent prior to the experiment. All the experimental protocols were approved by the Ethical Committee of Hunan University of Chinese Medicine, and the experiments were conducted in accordance with the approved guidelines.

2.2. Childhood maltreatment assessment

The Childhood Trauma Questionnaire-Short Form (CTQ-SF) is a 28-item retrospective self-report questionnaire that measures five different types of childhood abuse or neglect: sexual abuse (SA), physical abuse (PA), emotional abuse (EA), physical neglect (PN), and emotional neglect (EN) (Bernstein et al., 2003). Each subscale consists of five statements; the CTQ-SF includes three additional statements that are designed to detect the tendency to minimize or deny the extent of abuse (Minimal/Denial subscale). Each item is rated on a scale from 1 (never) to 5 (very often) and the ratings of the items on each subscale are

< 8). As 18 participants were lost to follow-up or did not complete the entire experiment, 42 integral EEG data were collected in total. Among the remaining participants, 8 invalid ERP data were excluded from the analysis because the valid segmentations for each condition were less than 30 (Huffmeijer et al., 2014; Marco-Pallares et al., 2011). Finally, we had two groups of 17 individuals (see Fig. 1). The two groups were matched for gender and age (range: 20–22 years of age; maltreated group *Mean* = 21.35, *SD* = 0.70; control group *Mean* = 21.59, *SD* = 1.18). All the participants were right-handed and had normal or

summed to yield a score for each type of trauma: higher scores indicate greater severity. Based on the guidelines recommended by Bernstein and Fink, childhood abuse or neglect was defined according to the following subscale cut-off scores: SA > 7; PA > 9; EA > 12; EN > 14; and PN > 9 (Bernstein and Fink, 1998). As mentioned above, young adults who had a history of childhood maltreatment were screened and randomly selected for the maltreated group based on these criteria. Non-maltreated students were screened for the control group using the following cut-off scores: SA < 6; PA < 8; EA < 9; EN<10; and PN < 8 (Bernstein and Fink, 1998). It should be noted that the current study employed the Chinese version of the CTQ-SF; studies have shown that this version has acceptable reliability and validity with Chinese adolescents and college students (Fu et al., 2005; Zhao et al., 2005). The Cronbach's α for the entire scale has been reported to be 0.60, while the subscales range between 0.51 and 0.71. The test-retest correlation for the entire CTQ-SF is 0.71, with the subscales ranging from 0.43 to 0.82 (Zhao et al., 2005).

2.3. Stimuli and procedure

The dot-probe paradigm is a commonly used method to assess interactions between attention and emotion in selective attention (MacLeod et al., 1986). One hundred and sixty-two face photographs, comprising 54 neutral, 54 negative (18 angry faces, 18 fearful faces, and 18 disgusted faces), and 54 happy expressions were selected from Chinese Facial Affective Picture System (CFAPS), which is a standardized and reliable tool that is widely used for emotion research with the Chinese population (Gong et al., 2011; Lu et al., 2005). Each picture of an emotional face was presented 6 times in a pseudorandom order. The whole experiment consisted of three blocks for a total of 648 trials (324 trials with happy faces, 108 trials with angry faces, 108 trials with fearful faces, and 108 trials with disgusted faces). All the affective faces were paired with neutral faces, and all the stimuli pairs were gender-balanced. The entire experiment lasted about 40 min.

Subjects performed a dot-probe task. An example of a trial sequence is presented in Fig. 2. The experiment was run using E-Prime 2.0 Software (Psychological Software Tools, Pittsburgh, PA, USA). Each trial was initiated by a central fixation cross for 500 ms. The paired photographs (affective *vs* neutral) were subsequently displayed on the left and right side of fixation for 800 ms, followed by a dot for 2000 ms on one side of the fixation point. The subjects were asked to determine the location of the dot and to press a key for "left" side and another key for "right", using their index fingers and middle fingers. Thus, the participants were exposed to one of two conditions in each trial: (1) Congruent—the locations of the affective photograph and the dot location were on the same side; (2) Incongruent—the locations were on
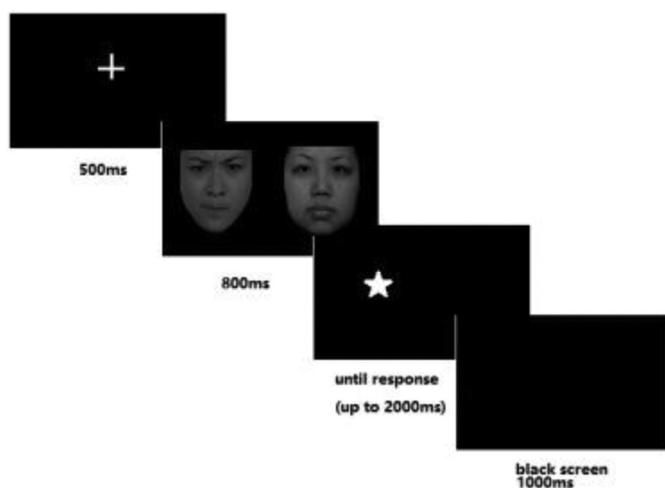

Fig. 2. Example trial sequences in the dot-probe task.

different sides.

2.4. EEG data acquisition and processing

The EEG data were recorded with a Net Amps 300 high-impedance EEG amplifier and NetStation software (Version 4.6) from a 64-electrode HydroCel Geodesic Sensor Net (Electrical Geodesic Inc. OR). The impedance of all the electrodes was maintained below 50 kΩ during data acquisition. All the electrodes were physically referenced to Cz (fixed by the EGI systems). The EEG data were amplified with a band pass of 0.1–200 Hz, using a sampling rate of 500 Hz.

EEG data were exported from NetStation and all EEG pre-processing was performed using custom MATLAB (Mathworks, Inc., Natick, MA) scripts and functions from the EEGLAB toolbox (Delorme and Makeig, 2004). The data were subsequently filtered by a band-pass filter (half-power cut-off at 0.1 to 30 Hz) with a roll-off of 12 dB/octave, and then re-referenced to the average reference. The EEG data were segmented into 1200 ms epochs with 200 ms pre-stimulus baseline and 1000 ms post-stimulus period, and inspected visually to identify bad channels and sources of artifacts. Independent component analysis (ICA) and ADJUST algorithms were used to identify and eliminate artifacts, including eye movements or blinks, carotid pulses, and generic discontinuities. A total of 64 ICA components were generated for EEG dataset of each participant. Epochs contaminated by incorrect responses were excluded.

The event-related potentials were averaged for each emotion separately, producing ERP waveforms under the four conditions: angry, disgusted, fearful, and happy faces. Then, baseline correction was applied over the 100 ms preceding face onset. Based on morphology and voltage topography of the grand-average ERPs, the P100 peak amplitude and N170 average amplitude for each electrode were calculated separately with a time window of 80–170 ms and 150–200 ms following stimulus onset. Occipital sites (O1 for the left, Oz for the midline, and O2 for the right) were selected for P100 analyses. Two clusters of three electrodes on bilateral occipitotemporal sites (10–10 systems sites: P1, P7, and P9 on the left; P2, P8, and P10 on the right) were chosen from each hemisphere, and the aggregated data from each hemispheric cluster were used in the N170 component analyses.

2.5. Statistical analyses

Independent *t*-tests were used to analyze group differences in age and CTQ-SF scores and the chi-square test was used to analyze the gender composition of the two groups. Reaction times (RTs) and accuracy from behavioral data were analyzed separately, using a $2 \times 2 \times 4$ repeated-measures multivariate analyses of variance (MANOVA) with Group (Maltreated *vs* Control) as a between-subjects factor, and Congruency (Congruent *vs* Incongruent) and Type of Emotion (angry, disgusted, fearful, and happy) as within-subject factors.

For the analysis of potential differences in P100 component amplitude and latency, we employed a repeated-measures multivariate analysis of variance (MANOVA) with Group (Maltreated *vs* Control) as a between-subjects factor, and Type of Emotion (angry, disgusted, fearful, and happy) and Electrode site (O1 for the left, Oz for the midline, and O2 for the right) as within-subject factors. The N170 analysis also employed a repeated-measures MANOVA with Group (Maltreated *vs* Control) as a between-subjects factor, and Type of Emotion (angry, disgusted, fearful, and happy) and Hemisphere (Left *vs* Right) as within-subject factors. A significance level of $\alpha = 0.05$ was employed. The Greenhouse–Geisser correction was applied to compensate for the violation of sphericity where required (Greenhouse and Geisser, 1959). The Bonferroni correction for multiple comparisons was used for the *t*-tests. The effect sizes of the main effects are reported as partial Eta-squared (η_p^2) and the interaction effects are reported as Cohen's *d*s for pairwise comparisons.

Table 2
Reaction time and accuracy in the maltreated and control groups.

Group	Emotion	Congruency	Reaction time (ms)		Accuracy (%)	
			Mean	Std errors	Mean	Std errors
Maltreated	Angry	Congruent	403.33	9.55	99.29	0.29
		Incongruent	406.75	10.40	99.41	0.22
	Disgusted	Congruent	403.47	10.58	99.06	0.25
		Incongruent	406.53	9.67	99.65	0.19
	Fearful	Congruent	402.25	10.18	99.29	0.29
		Incongruent	411.75	10.45	99.41	0.23
	Happy	Congruent	405.91	9.83	99.31	0.20
		Incongruent	407.66	10.08	99.08	0.31
Control	Angry	Congruent	417.13	16.09	99.41	0.25
		Incongruent	423.21	14.78	98.98	0.43
	Disgusted	Congruent	417.06	15.58	99.55	0.31
		Incongruent	420.65	15.98	99.22	0.33
	Fearful	Congruent	420.26	15.97	98.92	0.36
		Incongruent	424.10	14.22	98.94	0.39
	Happy	Congruent	422.78	15.24	98.24	0.25
		Incongruent	423.95	15.22	97.96	0.35

3. Results

3.1. Behavioral data

The two groups of participants did not differ significantly in age (t(32) = 0.71, p = 0.484), or gender (χ^2(1, N = 34) = 1.13, p = 0.287). As expected, the CTQ-SF scores of the maltreated group were significantly higher than those of the control group (EA: t(32) = 2.92, p = 0.006, d = 1.03; PA: t(32) = 2.72, p = 0.011, d = 0.83; EN: t(32) = 5.54, p < 0.001, d = 1.96; PN: t(32) = 6.14, p < 0.001, d = 2.17) (see Table 1).

The analysis of RT revealed a main effect of Congruency (F(1, 32) = 10.77, p = 0.003, η_p^2 = 0.25). Post-hoc tests revealed that participants, on average, were slower on respond to incongruent trials than they were on congruent trials (t(33) = 3.327, p = 0.002, d = 0.45)(see Table 2). None of the remaining main effects or interactions were significant. The results of the MANOVA are presented in Table 3.

The analysis of accuracy revealed a significant main effect of Type of Emotion (F(3, 96) = 4.26, p = 0.007, η_p^2 = 0.118) and a significant interaction between Congruency and Group (F(1, 32) = 4.74, p = 0.037, η_p^2 = 0.129). Post-hoc tests of the main effect found no significant differences between the four types of emotions (p > 0.05), while simple effect analyses of the significant interaction revealed that the maltreated group was more accurate than the control group on incongruent trials (t(32) = 2.242, p = 0.032, d = 0.80). The results of the MANOVA are presented in Table 4.

3.2. Electrophysiological data

The grand-average ERPs in response to emotional faces from bilateral occipitotemporal sites and occipital sites (O1, O2) are shown in Figs. 3 and 4. The amplitude and latency data of the P100 and N170 for the maltreated and control groups are shown in Tables 5 and 6.

Table 3
Analyses of variance results for the reaction time (ms) by group, type of emotion, congruency.

Effect	F	p	η_p^2
Group	0.71	0.407	0.022
Congruency	10.77	0.003	0.252
Type of emotion	1.66	0.180	0.049
Group × Congruency	0.10	0.760	0.003
Group × Type of emotion	0.22	0.880	0.007
Congruency × Type of emotion	0.55	0.549	0.017
Group × Congruency × Type of emotion	0.35	0.788	0.011

Table 4
Analyses of variance results for the accuracy (%) by group, type of emotion, congruency.

Effect	F	p	η_p^2
Group	3.08	0.089	0.088
Congruency	0.34	0.563	0.011
Type of emotion	4.26	0.007	0.118
Group × Congruency	4.74	0.037	0.129
Group × Type of emotion	2.52	0.062	0.073
Congruency × Type of emotion	0.57	0.633	0.018
Group × Congruency × Type of emotion	0.75	0.526	0.023

For the P100 amplitude, the MANOVA with repeated-measures analysis revealed a main effect of Electrode site (F(2, 64) = 6.33, p = 0.01, η_p^2 = 0.17), but no main effect of Group (F(1, 32) = 3.47, p = 0.072, η_p^2 = 0.10) or Type of Emotion (F(3, 96) = 0.68, p = 0.47, η_p^2 = 0.02). No interaction effects were statistically significant. Post-hoc tests revealed that larger P100 amplitudes were elicited at the right (O2) electrode site than at the left (O1) electrode site (t(33) = 2.779, p = 0.028, d = 0.40) and the midline (Oz) electrode site (t(33) = 3.058, p = 0.014, d = 0.21).

The P100 latency data for each Type of Emotion and each Electrode site are shown in Table 5. The MANOVA found no significant main effects or interaction effects for the P100 latency.

Analysis of the group-averaged N170 amplitudes revealed a significant main effect of Group (F(1, 32) = 6.97, p = 0.013, η_p^2 = 0.18) and Hemisphere (F(1,32) = 18.35, p < 0.001, η_p^2 = 0.36), and a significant interaction between Group and Type of Emotion (F(3, 96) = 4.63, p = 0.005, η_p^2 = 0.13). No other main effects or interactions were significant. The MANOVA results are presented in Table 7.

Post-hoc analyses revealed that N170 was significantly more negative (*i.e.*, had a significantly larger amplitude) in the maltreated group than in the control group (t(32) = 2.641, p = 0.013, d = 0.93). N170 also showed a significant right-lateralization pattern (*i.e.*, had a significantly larger amplitude in the right hemisphere compared to the left; t(33) = 4.336, p < 0.001, d = 0.75). The interaction between Group and Type of Emotion showed that angry (t(32) = 2.472, p = 0.019, d = 0.87), fearful (t(32) = 3.217, p = 0.003, d = 1.14) and happy faces (t(32) = 2.850, p = 0.008, d = 1.01), but not disgusted faces (t(32) = 1.404, p = 0.170, d = 0.50) elicited a N170 with a larger amplitude in the maltreated group, compared to the control group. The topographical maps of N170 from both groups are shown in Fig. 5.

N170 latency data for each Type of Emotion and Hemisphere are shown in Table 6. No main effects or interactions were significant.

4. Discussion

Previous studies have shown that maltreated children are characterized by hyper-sensitivity to angry facial expressions, but knowledge about the neural mechanism of emotional face processing in young adults who have a history of childhood maltreatment is limited. The current study examined the processing of faces expressing different emotions (angry, fearful, disgusted, and happy faces) in young adults with a history of maltreatment as children and a matched control group. In addition, we sought to investigate whether any N170-amplitude discrepancies between our two groups were valence-independent or valence-dependent.

In the present study, the ERP data showed that the maltreated group, compared with the non-maltreated group, had larger N170 amplitudes when processing angry, fearful, and happy faces. Consistent with the ERP results, the behavioral data revealed that the maltreated group had a higher mean accuracy and a shorter mean RT than the control group had, although the difference between the two groups was not statistically significant.

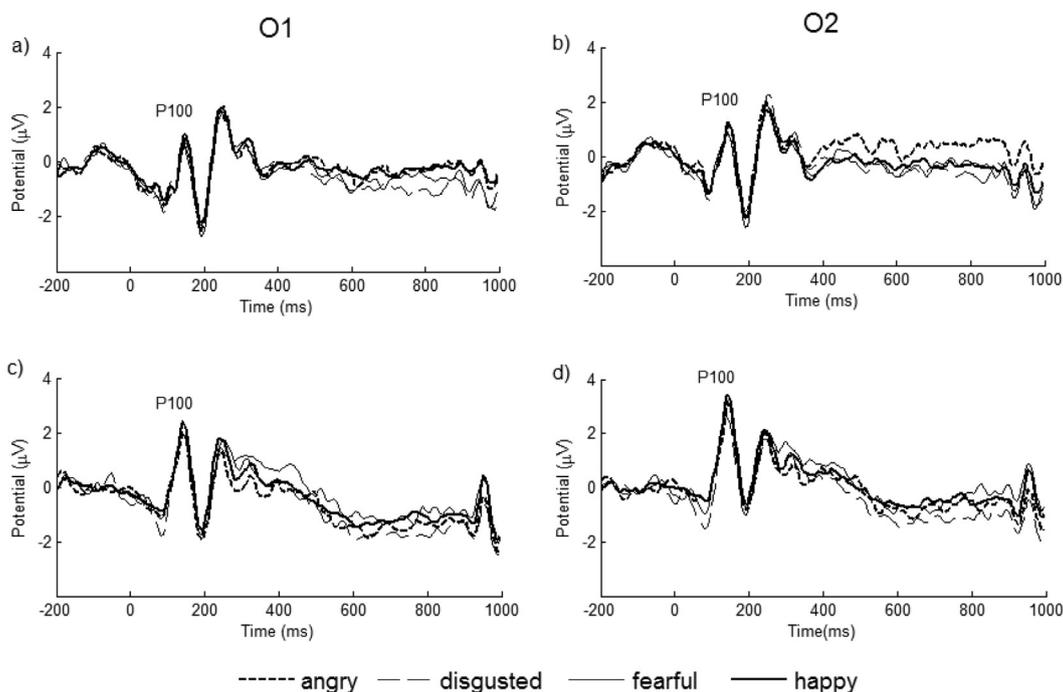These main findings suggest that victims of childhood maltreatment

Fig. 3. Grand average ERPs in response to emotional (angry, disgusted, fearful and happy) faces at left (O1) and right (O2) occipital sites. The (a) left site (O1) and (b) right site (O2) in maltreated group, (c) left site (O1) and (d) right site (O2) in control group are represented respectively.

may be hyper-vigilant when processing emotional facial expressions. In addition, they are in line with a recent study that found trauma exposure was associated with generalized heightened responsivity to positive as well as threat-related emotional cues (Chu et al., 2016). This pattern of larger N170 amplitudes to happy and some kinds of negative faces (angry and fearful) in adults reporting a history of childhood maltreatment points to broader alterations in the early stages of emotional face processing than were previously thought, and that a selective response to threat cues (such as anger) may only occur in the later stages of processing faces, as evidenced by previous studies (Pollak and Tolley-Schell, 2003).

The results of larger N170 amplitudes in response to angry and fearful faces in the maltreated group are consistent with previous findings that indicate "hypervigilance" to threat-related cues (McCrory et al., 2010; McCrory et al., 2013) among children and adults who report a history of maltreatment (Dannlowski et al., 2013; Dannlowski et al., 2012). This heightened sensitivity might facilitate the identification of threatening situations, and hence, protect against further maltreatment. For instance, a relatively superior ability to perceive fearful facial expressions, which are often indicative of immediate
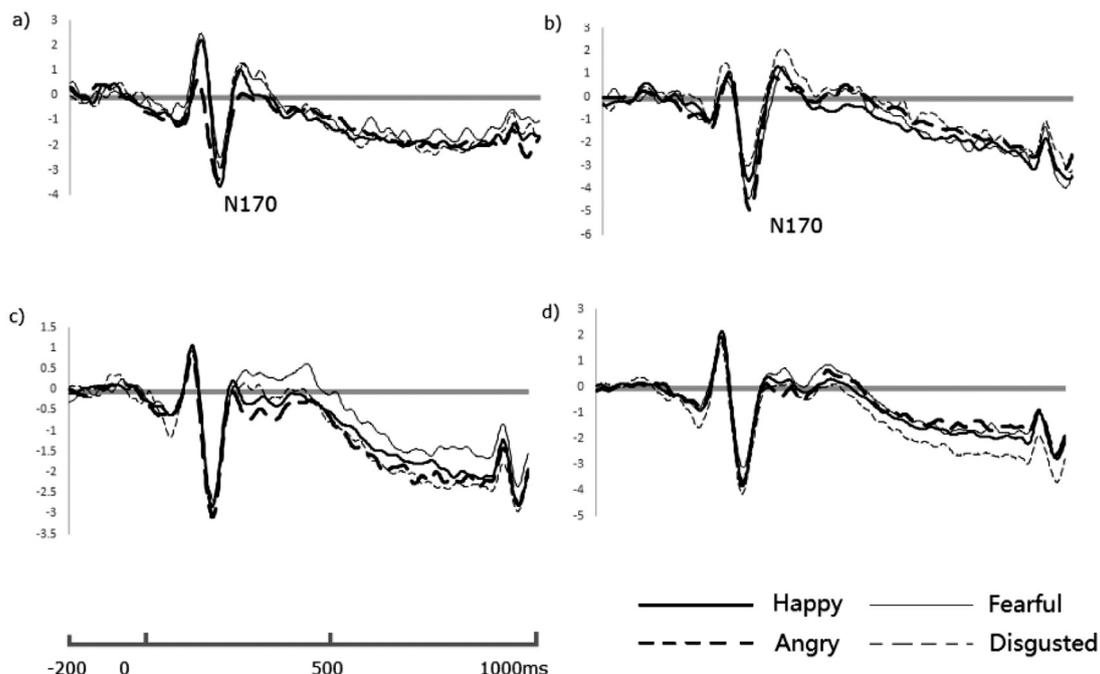

Fig. 4. Grand average ERPs in response to emotional (angry, disgusted, fearful and happy) faces in bilateral occipitaltemporal sites. The (a) left sites and (b) right sites in maltreated group, (c) left sites and (d) right sites in control group are represented respectively.

Table 5

Descriptive statistics for the amplitude (μV) and latency (ms) of P100 for each type of emotion in left (O1), midline (Oz) and right (O2) electrode sites.

Electrode sites	Emotion	P100 amplitude Mean(std errors)		P100 latency Mean(std errors)	
		Maltreated group	Control group	Maltreated group	Control group
Left (O1)	Angry	2.14(0.90)	3.08(0.51)	143.06(4.53)	137.88(4.29)
	Disgusted	1.32(0.55)	3.06(0.49)	139.06(4.60)	136.94(3.30)
	Fearful	1.53(0.62)	3.37(0.57)	138.59(4.60)	137.65(3.76)
	Happy	1.47(0.57)	3.77(0.62)	141.65(4.41)	141.88(4.72)
Midline (Oz)	Angry	2.89(0.94)	3.50(0.69)	139.06(5.67)	140.47(4.57)
	Disgusted	1.86(0.45)	3.30(0.65)	136.47(5.20)	136.71(4.23)
	Fearful	2.02(0.59)	3.75(0.73)	133.41(5.53)	141.65(4.54)
	Happy	1.86(0.55)	3.92(0.67)	140.94(5.41)	136.94(5.34)
Right (O2)	Angry	3.49(1.20)	3.91(0.78)	134.82(4.88)	138.12(4.55)
	Disgusted	2.54(0.47)	3.70(0.67)	135.29(4.68)	131.06(4.81)
	Fearful	2.96(0.61)	3.94(0.78)	137.18(4.46)	135.06(4.49)
	Happy	2.43(0.50)	4.41(0.75)	142.12(4.26)	137.65(5.24)

environmental threats, may be particularly useful for this group.

However, we should note that an enhanced N170 component was also evoked by happy faces. These results suggest that the hyper-sensitivity to emotional information is valence-independent. A possible explanation is that the victims of childhood emotional abuse have poor valence discriminatory abilities for different facial emotions (Fries and Pollak, 2004; Pollak et al., 2000; van Harmelen et al., 2013; Vorria et al., 2006). Or they might misinterpret all emotional faces as threatening, for example, happy faces may be interpreted as a mask for more malevolent emotions, as being laughed at (Pollak et al., 2000).

Another point worth noting is that our study did not find significant differences in P100 amplitude between the maltreated and control groups, which is inconsistent with our hypothesis about the P100. The P100 component, prior to the face-specific N170, appears to reflect more than simple low-level features of stimuli and it may indicate the earliest phase of automatic visual processing that seems to be sensitive to facial stimuli (Itier and Taylor, 2004; Taylor, 2002), whereas the N170 is thought to be an index of configural face processing (Bentin et al., 1996; Bentin and Deouell, 2000). This dissociation between P100 and N170 suggests that the atypical processing of emotional faces in young adults with a history of maltreatment occurred around 170 ms after stimulus onset, later than 100 ms in the earliest stage of general visual processing. In other words, the abnormality of early perceptual processing of emotional faces in the maltreated group may not have begun during the earliest stage of automatic processing.

Our results also found that the N170 and P100 elicited by emotional facial expressions had significantly greater amplitudes in the right hemisphere of both groups. This lateralization is consistent with previous findings and provide evidence for right-hemispheric dominance for processing faces (Bentin et al., 1996; Bentin et al., 2006; Christianson et al., 1995). It also suggests that the right lateralization effects for emotional face processing were not affected by the history of childhood maltreatment.

The present study provides biological evidence of altered neural

Table 7

Analyses of variance results for the N170 amplitude (μV) by group, type of emotion, hemisphere.

Effect	F	p	η_p^2
Group	6.97	0.013	0.18
Hemisphere	18.35	<0.001	0.36
Type of emotion	0.23	0.877	0.01
Group × Hemisphere	0.21	0.652	0.01
Group × Type of emotion	4.63	0.005	0.13
Hemisphere × Type of emotion	0.54	0.657	0.02
Group × Hemisphere × Type of emotion	1.21	0.311	0.04

processing of emotional facial expressions in young adults with a history of childhood maltreatment. However, the current study has several limitations. First, the incidence and severity of childhood maltreatment were based on retrospective self-reports, which have an inherent potential for recall bias, reporting bias, and false negatives (Hardt and Rutter, 2004). In future studies, multiple measures (*e.g.*, parents' reports and semi-instructed interviews) should be used to minimize these errors. We should note, however, a recent study found that biases were minimal in retrospective self-reports of maltreatment in childhood (Fergusson et al., 2011). Second, there were confounding factors related to the study outcomes that we did not measure, such as the anxiety level of the participants. Anxiety is associated with biases in attention to threat-related information (Bar-Haim et al., 2007; Puliafico and Kendall, 2006). Previous studies have found that anxious individuals (individuals with different clinical disorders and highly anxious nonclinical individuals), exhibited threat biases during the dot-probe task (Holmes et al., 2008; Zvielli et al., 2014). Therefore, further studies need to assess and control for potential anxiety or mood confounds on early ERP component responses to emotional faces. Third, our sample size was small and the sample did not include individuals with psychopathologies. While being somewhat consequential for ecological validity, the overlap in symptoms between victims of childhood
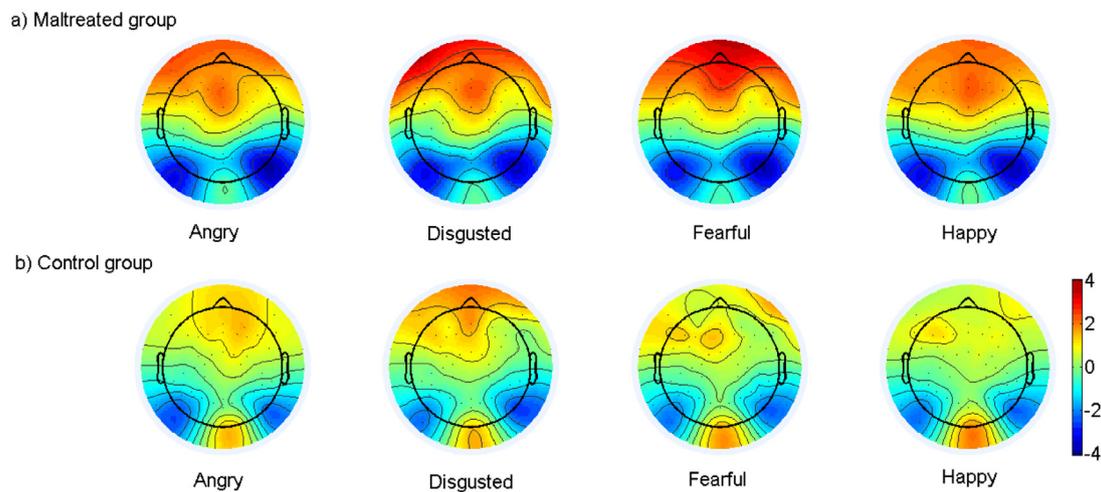
Table 6

Descriptive statistics for the amplitude (μV) and latency (ms) of N170 for each type of emotion in left and right hemispheres.

Hemisphere	Emotion	N170 amplitude Mean(std errors)		N170 latency Mean(std errors)	
		Maltreated group	Control group	Maltreated group	Control group
Left	Angry	−2.37(0.55)	−1.27(0.33)	195.24(2.66)	196.25(2.60)
	Disgusted	−2.10(0.53)	−1.23(0.34)	191.25(5.95)	198.39(4.02)
	Fearful	−2.58(0.55)	−0.94(0.34)	194.71(2.97)	196.20(3.78)
	Happy	−2.42(0.44)	−.95(0.30)	184.73(6.87)	189.76(5.07)
Right	Angry	−4.11(0.60)	−2.34(0.38)	195.98(2.96)	195.16(2.41)
	Disgusted	−3.52(0.62)	−2.83(0.43)	189.61(6.28)	196.37(3.50)
	Fearful	−4.12(0.61)	−2.02(0.34)	193.78(2.69)	194.16(3.11)
	Happy	−4.15(0.68)	−2.40(0.36)	184.08(6.66)	188.35(5.29)

Fig. 5. The topographical map of N170 component (150–200 ms) in the (a) maltreated group and the (b) control group elicited by angry, disgusted, fearful and happy facial expressions.

maltreatment with or without concurrent psychopathologies, especially in terms of emotional and attentional regulation (Fonzo et al., 2016), would have precluded the aims of our study. Regardless, our results require replication in larger samples to assess their potential for clinical application.

5. Conclusion

The present study explored the neural mechanism of emotional facial-processing in young adults with a history of childhood maltreatment, using event-related potentials. Our results support the hypothesis that a history of childhood maltreatment has a relationship with the processing of emotional expressions in adulthood.

Acknowledgment

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.psychres.2019.03.024.

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