Child Abuse & Neglect 154 (2024) 106874

Contents lists available at ScienceDirect

Child Abuse & Neglect

journal homepage: www.elsevier.com/locate/chiabuneg

EEG responses to infant faces in young adults can be influenced by the quality of early care experiences with caregivers

Micol Gemignani *, Simona de Falco

Department of Psychology and Cognitive Science, University of Trento, Rovereto, TN, Italy

ARTICLE INFO

Keywords:
Infant cues
Emotion
Event-related potentials
N170
Acceptance-Rejection theory

ABSTRACT

Background: The quality of early experiences with caregivers affects individual adjustment and can modulate adults' responses to salient social stimuli, like infant faces. However, in the framework of Interpersonal Acceptance-Rejection Theory (IPARTheory), no research to date has examined whether early experiences of acceptance or rejection from caregivers are associated with individual differences in the electrophysiological (EEG) responses to infant faces.

Objective: This study examined the associations between the perceived quality of care during childhood and the behavioral and EEG responses to infant and adult faces in non-parent young adults.

Methods: $N = 60$ non-parent young adults (30 males; 30 females) completed an Emotion Recognition task displaying emotional and unemotional infant and adult faces during an EEG recording. Memories of past care experiences with mothers and fathers were collected using the short form version of the Parental Acceptance-Rejection scale.

Results: At the behavioral level, slower Reaction Times (RTs) in recognizing all faces were related to higher levels of perceived maternal rejection in young adults; in particular, males who reported higher levels of maternal rejection displayed longer RTs in recognizing faces compared to females. At the neurophysiological level, as the level of perceived paternal rejection increased, the N170 amplitude to infant faces increased. Females who reported higher levels of paternal rejection, compared to males, had a larger increase in the N170 amplitude and a larger decrease in the LPP amplitude in response to emotional faces.

Conclusions: While a higher perception of maternal rejection hindered the behavioral responses of adults in recognizing faces, those who felt more rejected by their own father during childhood showed an enhanced N170 amplitude to infant faces. This might reflect a greater need for discrimination resources, at a very early stage of infant face processing, in those adults who perceived higher levels of paternal rejection. Adults' sex modulated the associations found at the behavioral and neurophysiological levels. Overall, our findings extended the IPARTheory postulates that being neglected during childhood might trigger perceptual changes in adults, hindering the elaboration of social cues like infant and adult faces at different levels.

1. Introduction

Individual well-being relies to a great extent on the nature of intimate relationships (Bowlby, 1969/1982). The Interpersonal

* Corresponding author at: Department of Psychology and Cognitive Science, University of Trento, Corso Bettini 84, 38068 Rovereto, TN, Italy.
E-mail address: micol.gemignani@unitn.it (M. Gemignani).

https://doi.org/10.1016/j.chiabu.2024.106874
Received 8 November 2023; Received in revised form 26 May 2024; Accepted 29 May 2024

Acceptance-Rejection Theory (IPARTheory; Rohner, 2021) posits that the feeling of being cared for by significant others is a fundamental human need, associated with many positive outcomes regarding individuals' mental and physical health. In particular, early experiences of care from caregivers seem to be essential for individuals' later adjustment (Khaleque & Rohner, 2002; Khaleque & Rohner, 2012). Children who perceive more acceptance by their own parents show more positive psychological, social, behavioral, and emotional developmental outcomes (e.g., higher rates of self-esteem and social competence, lower rates of depression and behavioral problems). On the other hand, parental rejection can have negative effects on individuals' mental health, sense of well-being, physical health, and interpersonal relationships (Rohner, 2004; Khaleque & Rohner, 2002; Rohner & Khaleque, 2010; Rohner, 2021). The quality of care perceived from caregivers might also influence the development of stable social, emotional and cognitive dispositions in individuals (Rohner et al., 2012); these mental representations, similar to Internal Working Models in the Attachment theory (Bowlby, 1969/1982), tend to extend from childhood into adulthood in the absence of any counter experiences (Ripoll-Núñez & Carrillo, 2016; Seyedmousavi et al., 2022). For instance, individuals who feel more rejected by their own caregivers during childhood tend to develop cognitive distortions relative to personal relationships as being unpredictable, untrustworthy, and hurtful (Rohner et al., 2012).

Therefore, differences in the early experiences with caregivers might lead to distinct emotional and cognitive organizations in adults, guiding their responses when confronted with salient social stimuli, like infant faces (Spangler et al., 2010). Nonetheless, whether the quality of early care can modulate adults' responses to infant faces has been poorly investigated in the framework of IPARTheory (Gemignani et al., 2022; Gemignani, Giannotti, & de Falco, 2024; Gemignani, Giannotti, Rigo, & de Falco, 2024; Senese et al., 2018); in particular, no research to date has adopted an EEG methodology to address this topic. Overall, furthering the understanding on this topic would be valuable, as individual variations in infant face processing can provide an early indication of the quality of caregiving practices (e.g., Kuzava et al., 2019; Vuoriainen et al., 2022), which can be carried out by both parents and non-parents (e.g., Abraham & Feldman, 2018; Glasper et al., 2019).

1.1. EEG responses to infant faces

Given their optimal temporal resolution, Event-Related Potentials (ERPs) have been widely used to investigate differences in individual responses to infant faces occurring at different stages of processing (Vuoriainen et al., 2022). ERPs are waveforms of the EEG signal averaged across multiple repetitions of a stimulus. ERPs are generally defined by their polarity (positive = "P" or negative = "N") and by the time window they occur (milliseconds; ms). The amplitude in microvolts (μv) of ERPs might vary depending on the experimental condition, providing an index of the strength and cognitive resources required for a stimulus detection. Among the different ERPs, previous studies on infant face processing have focused on the N170, P300 and Late Positive Potential (LPP) waveforms (Vuoriainen et al., 2022). The N170, peaking at around 170 milliseconds (ms) after the stimulus onset at temporal-occipital regions, reflects the perceptual processing and structural encoding of facial features (Eimer, 2011). The LPP and P300 components, which are positive deflections beginning at around 300 ms after the stimulus onset at parietal/centroparietal regions, reflect the output of attentional processes for motivationally salient stimuli and top-down cognitive processes (Hajcak & Foti, 2020). Given that the nomenclatures used in different studies do not uniformly conform to separate definitions, the P300 and LPP components have been interpreted altogether (i.e., in terms of a P300/LPP complex) in a recent meta-analysis (Vuoriainen et al., 2022). However, considering that the P300 has been predominantly observed in oddball task paradigms, where target stimuli are presented less frequently (e.g., 20%) compared to standard stimuli (e.g., 80%; see Luck, 2014), we referred to our target component as LPP, given that different experimental stimuli were presented at equal frequencies in this study (Vuoriainen et al., 2022).

Generally, it has been demonstrated that infant faces elicit larger amplitudes, at both early (N170) and later (P300/LPP) stages of face processing, than adult faces (Kuzava et al., 2020; Vuoriainen et al., 2022). In particular, while distressed infant faces elicited a larger N170 response in some studies (Proverbio et al., 2006; Rodrigo et al., 2011; Doi & Shinohara, 2012; Peltola et al., 2014; Dudek & Haley, 2020), other research failed to find such an effect on the N170 amplitude (Malak et al., 2015; Maupin et al., 2019; Rutherford, Byrne, et al., 2017; Rutherford, Maupin, et al., 2017a). Differently, a larger P300/LPP amplitude was found in response to personally significant faces, like own child's faces (Bick et al., 2013; Grasso et al., 2009; Weisman et al., 2012), own child's faces with crying expressions (Doi & Shinohara, 2012), and romantic partners' faces (Guerra et al., 2012). Moreover, the P300/LPP amplitude was found modulated by the emotional valence of faces, being generally larger for emotional versus neutral faces (Olofsson et al., 2008; Schupp et al., 2004).

1.2. The contribution of early care experiences with caregivers

Accumulating evidence has indicated that variations in the N170 and P300/LPP amplitudes to infant faces can be related to different characteristics of adults, such as their levels of anxiety or depression (Malak et al., 2015; Noll et al., 2012; Rutherford, Byrne, et al., 2017). Among the different factors that might have an influence on the ERP responses to infant faces (for a meta-analysis, see Kuzava et al., 2020), representations of attachment relationships have been associated with individual differences in the N170 and P300/LPP amplitudes. Fraedrich et al. (2010) found that mothers with a insecure attachment representation, compared to those with an secure attachment representation, showed a larger N170 amplitude in response to infant faces, independently of the emotional valence of faces (Fraedrich et al., 2010). Differently, mothers with a secure attachment representation showed a larger P300 amplitude to infant faces (Fraedrich et al., 2010). Similarly, Leyh et al. (2016) demonstrated that mothers with an insecure attachment representation, compared to those with a secure attachment representation exhibited a larger N170 amplitude in response to infant faces with negative facial expressions. An increased P300 amplitude to infant emotional faces was found in securely versus insecurely-attached mothers; in addition, securely-attached mothers detected more clearly the emotional expressions of infants at the behavioral level (Leyh et al., 2016). Differently, Groh and Haydon (2018) demonstrated that mothers with a secure attachment representation, compared to those with an insecure attachment representation, showed an more attenuated P300 amplitude in response to distressed infant faces; nonetheless, in line with previous evidence, mothers with a secure attachment representation were more accurate in identifying infant distress at the behavioral level (Groh & Haydon, 2018). Lowell et al. (2023) did not find any effects of the type of attachment of mothers on the P300 amplitude to infant faces. In a sample of non-parents, Ma et al. (2017) found that anxiously-attached women, compared to avoidantly-attached women, exhibited a larger N170 amplitude to infant faces. Generally, securely compared to insecurely-attached women showed a larger P300 amplitude to infant faces and shorter RTs in recognizing infant facial expressions (Ma et al., 2017).

Following an efficiency model of neural processing (see Lowell et al., 2023), it might be more demanding, for individuals with insecure attachment representations, to process structural features of infant faces (i.e., as reflected by a larger N170 amplitude). Differently, the effects of attachment representations on the P300 amplitude have been mixed (e.g., Groh & Haydon, 2018; Leyh et al., 2016). It should be noted that the aforementioned studies included only women, so the generalizability of findings is limited. To date, only one study (Waller et al., 2015) investigated men's ERP responses to infant cues accounting for their attachment representations; however, no results on the N170 or P300/LPP were highlighted. Given the overall scarcity of ERP studies on men (Kuzava et al., 2020), enhancing the knowledge on the potential factors underlying men's caregiving responses is valuable, especially considering their increasing involvement in caregiving activities over recent years (Bataille & Hyland, 2023). Therefore, a more comprehensive understanding of the factors associated with adults' responses to infant cues is needed; in doing so, a broader focus on either males and females would potentially help to comprehend whether sex has a role in modulating the effects of different variables on infant cue processing.

1.3. The present study

The quality of individuals' affective relationships early in life and the potential consequences thereof have captured the attention of numerous researchers within the field of social and emotional development. To investigate the contribution of early care experiences with caregivers, the present work was grounded in the theoretical perspective of IPARTheory (Rohner, 2021). In a mixed sample of non-parent young adults, we primarily investigated whether the perceived quality of care from caregivers would be associated with the N170 and LPP amplitudes in response to emotional and unemotional infant and adult faces. Since we implemented an active EEG task in this study, behavioral data (RTs) were also considered in the analyses. Eventually, as we included both females and males in our sample, we explored whether sex would modulate the relationships between the quality of care experiences and ERP and behavioral responses to adult and infant faces.

At the behavioral level, we expected that adults who felt more rejected during childhood would show longer RTs in recognizing infant facial expressions. At the neurophysiological level, we expected that infant faces would elicit a larger N170 amplitude than adult faces, and that those adults who felt more rejected during childhood would show a larger N170 amplitude to infant compared to adult faces. As for the LPP, we expected that the LPP amplitude would be larger in response to emotional faces compared to neutral faces. Given the mixed findings on the effect of early care experiences on the LPP amplitude, we could not formulate a priori hypotheses on that association. Similarly, considering the exploratory nature of the investigation of sex in modulating the associations among the variables, we refrained from deriving a priori hypotheses.

2. Methods

2.1. Participants

$N = 64$ (31 males; 33 females) participants were recruited to complete an Emotion Recognition task during an EEG recording and some online questionnaires. The sample size was consistent with previous research on the topic (i.e., $N = 65$ Weisman et al., 2012; $N =$

Table 1
Characteristics of the study participants grouped by sex; N = number; M = mean; % = Percentage; SD = standard deviations.

Group or variable	Females (n = 30; 50 %)		Males (n = 30; 50 %)	
	N	M (SD) or %	N	M (SD) or %
Nationality	30		30	
Italian	28	93 %	30	100 %
Non-Italian	2	7 %	0	0 %
Education	30		30	
Middle School	0	0 %	1	3.5 %
High School	18	60 %	13	43.5 %
Bachelor's Degree	8	27 %	10	33 %
Master's Degree	3	10 %	3	10 %
Postgraduate/Doctorate	1	3 %	3	10 %
Age	30	22 (3.0)	30	23.2 (3.2)
PARQmother	30	40.4 (12.4)	30	36.3 (7.5)
PARQfather	30	44.6 (16.1)	30	43.9 (10.5)

63 Rutherford, Maupin, et al., 2017c; $N = 59$ Lowell et al., 2023; $N = 63$ Rutherford et al., 2021; $N = 68$ Peoples et al., 2022). The participants were mainly undergraduate students from the University of Trento. To be included in the final sample, participants should report i) to have no prior history of neurological or psychiatric disorders and to be free from any psychotropic medication; ii) to have a normal or correct-to-normal vision; iii) to be between 18 and 30 years of age (i.e., young adults; Arnett et al., 2014) and to be an Italian native speaker; iv) to have no children and no daily contact with children. In total, 4 participants were excluded from the final sample based on these criteria ($n = 1$ participant was diagnosed with Tourette Syndrome; $n = 2$ participants reported having a psychiatric disorder or taking psychotropic medications; $n = 1$ participant was outside the 18–30 age range). The final sample was composed of $N = 60$ participants (30 males; 30 females). Six out of 60 participants were left-handed. While 27 participants reported to have a normal vision, 33 participants reported to have a corrected-to-normal vision. All participants were White and identified as cisgender; moreover, none of them reported a different sex rather than “male” or “female” (no participants reported to be intersex). All participants but two reported to be Italian; one participant reported to be Romanian and another one reported to have a double (i.e., Italian and German) nationality. A broader overview of the study participants is reported in Table 1. The study was conducted in accordance with the Declaration of Helsinki. The ethics committee of the University of Trento approved the study. All participants signed the informed consent before participating.

2.2. Experimental task and stimuli

In the EEG laboratory, participants were first asked to complete a brief self-report to provide some demographic information. They sat in a dimly lit room and performed an Emotion Recognition Task (Fig. 1), in which they were asked to evaluate infant and adult faces displaying three different (happy, neutral, sad) facial expressions. The task was developed using OpenSesame (Mathôt et al., 2012). Each trial started with the presentation of a fixation cross at the center of the screen with a jittered duration of 550–850 ms. A stimulus display was then presented for 1000 ms, followed by a response display until the response of participants (time-out 5000 ms), and then a blank screen for 750 ms. Participants were asked to i) be as accurate as possible; ii) minimize eye or body movements during the EEG recording; iii) put their index, middle and ring fingers of the preferred hand on the “c”,“v”,“b” keys on the keyboard. Participants were instructed to look at each face and, only after its offset, indicate whether the face expressed a happy, neutral, or sad expression. The matching between the responses (“happy”, “neutral”, “sad”) and keys in the keyboard (“c”, “v”, “b”) was randomly assigned to each participant. Standardized experimental stimuli included 36 faces (6 males; 6 females) of White infants aged 4–12 months extracted from the Tromso Infant Faces Database (TIF; Maack et al., 2017) and 36 faces (6 males; 6 females) of White adults taken from the Karolinska Directed Emotional Faces (KDEF; Lundqvist et al., 1998). For each identity, three facial expressions displaying happy, neutral, and sad emotional content were chosen. The stimuli were cropped into an oval shape, converted into gray scale and matched for size and luminance using Photoshop. They were presented against a uniform gray background. Participants completed a practice block of 8 trials, then 4 test blocks of 72 trials. In total, 48 trials were presented for each condition in the test phase. A self-paced break followed each block. The trial order was randomized within each block. The conditions were balanced within the block. The completion of the task took around 16 min.

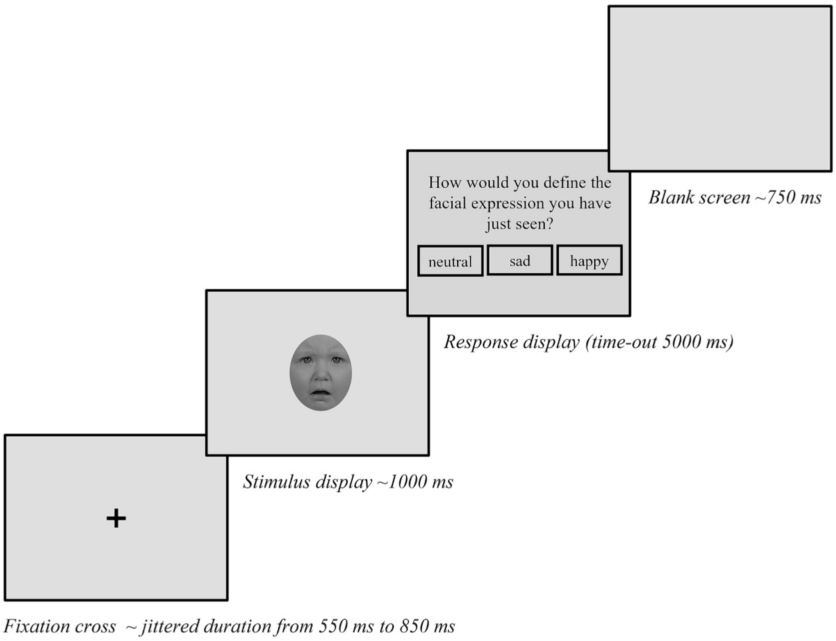

Fig. 1. An example of a trial in the Emotion Recognition task. In the actual task, the responses in the response display were displayed in the center of the screen.

2.3. EEG acquisition and pre-processing

A continuous EEG activity was recorded using an eego sports system (ANTNeuro) at a sampling frequency of 1000 Hz, from 64 Ag/AgCl shielded electrodes referenced to CPz and placed in the standard 10–10 locations on an elastic cap (Brain Products). An additional electrode (Electrooculogram, EOG) was placed under the left eye. A conductive gel was applied to the electrodes. Impedance was kept under 20 kΩ. Data pre-processing was performed with the MATLAB toolboxes EEGLAB v2022.0 (Delorme & Makeig, 2004) and ERPLAB (Lopez-Calderon & Luck, 2014). EEG data was re-referenced offline to the average of electrodes; mastoids and EOG were excluded. EEG data were band-pass filtered, with cutoffs of 0.1 and 30 Hz. Epochs were segmented for each trial, starting from −1000 ms to 2000 ms from the stimulus onset. A long baseline correction (−1000 ms) was performed to have a more accurate estimate of the voltage offsets. For one participant, the channel F8 was classified as bad and interpolated (i.e., the F8 electrode stopped working during the EEG montage; the EEG cap was then repaired). Artifacts related to eye movements, head movements and muscle contractions were first rejected by eye inspection. Independent Component Analysis (ICA; RUNICA algorithm) was additionally performed to remove noise components from the signal, especially those related to eye-blinks. ICA components were visually inspected and selected for deletion only when their topography indicated a source of noise. The IClabel tool (Pion-Tonachini et al., 2019) was also used for this purpose. After excluding incorrect trials, accepted epochs were averaged for each condition (on average, $N = 44.5$ epochs were considered for adult happy condition; $N = 44.8$ for adult neutral condition; $N = 44.2$ for adult sad condition; $N = 45.1$ for infant happy condition; $N = 44.8$ for infant neutral condition; $N = 44.9$ for infant sad condition). ERPs were computed for each condition, only for correct trials, in discrete time windows and electrode groups. The N170 component was defined as the average activity in the 170–230 ms time window following the stimulus onset across the parieto-occipital electrodes P7, P8, P07, P08 (see Rossion & Jacques, 2008 for review). The LPP component was defined as the mean activity in the 300–700 ms time window following the stimulus onset. The LPP was averaged over the parietal electrodes PZ, P1, P2, POZ, PO3, PO4, which showed the most prominent waveform (Peltola et al., 2014, 2018). The N170 and LPP amplitudes were analyzed after being averaged across the selected channels and time windows.

2.4. Self-reports

Self-reports were completed using Qualtrics (Qualtrics, Provo, UT). An ad-hoc questionnaire was used to collect socio-demographic information. Bem Sex-Role Inventory (BSRI; Bem, 1974) was used to measure participants' adherence to gender roles related to femininity and masculinity. The results related to this measure were not presented in this study.

The Italian validated short form version (Senese et al., 2016) of the Parental Acceptance-Rejection scale (PARQ) (Rohner, 2005) was administered. The measure consists of two scales (i.e., PARQmother and PARQfather) assessing the perceived experiences of care with one's mother and father during childhood. Each scale has 24 items and originates a total maternal/paternal score; higher scores mean higher levels of maternal/paternal rejection. The score of each scale ranges from 24 to 96; in an Italian sample (Senese et al., 2016), mean values of 36.1 for PARQmother and 38.5 for PARQfather were previously reported. Each scale consists of four dimensions: (1) warmth/affection, (2) hostility/aggression, (3) indifference/neglect, (4) undifferentiated rejection. Participants indicated how well each statement described their past experiences of care using a four-point Likert scale (from 4 = *almost always true* to 1 = *almost never true*). In this study, the two total scores had a good reliability: PARQmother $\alpha = 0.91$; PARQfather $\alpha = 0.93$.

2.5. Data analysis

Statistical analyses were performed with R studio (version 4.2.2). Preliminary comparisons between males and females were tested through two-tailed *t*-tests for self-reported numerical variables (i.e., age, PARQmother and PARQfather). Pearson's Chi-squared test was used to test potential differences between males and females in the education level. The accuracy level of participants in performing the task was overall high (i.e., on average, 90 % of accurate trials: 88 % for infant happy condition; 74 % for infant neutral condition; 94 % for infant sad condition; 98 % for adult happy condition; 92 % for adult neutral condition; 92 % for adult sad condition). Due to a potential ceiling effect related to the accuracy, only RTs data were considered in the behavioral analyses. The distributions of data were checked. Then, Linear mixed-effects models (LMM; Bates et al., 2015) were implemented to account for the contribution of face age (infant, adult), emotional valence (happy, neutral, sad), sex (male, female), PARQmother and PARQfather on the behavioral (RTs) and neurophysiological (N170, LPP) variables. The models included random intercepts for participants. PARQmother and PARQfather were centered by subtracting the mean values across participants and tested in distinctive models; therefore, we adopted a more differentiated approach to investigate the effects of the perceived care experiences with each caregiver separately. The effects found with LMMs were reported according to the Type III Analysis of Variance with Satterthwaite's method. Post-hoc comparisons were Bonferroni corrected. The effects were considered up to three-way interactions. The results of the main models are reported in Supplementary Material 1 (SM1). The stability of the results was checked by considering only the participants ($n = 52$) who had both acceptable behavioral and ERP data. The results of these supplementary analyses are reported in Supplementary Material 2 (SM2).

3. Results

3.1. Preliminary results

No statistically significant differences between males and females emerged in terms of age, education level, PARQmother and

PARQfather. PARQmother and PARQfather showed a positive correlation ($r(58) = 0.6$, $p < .001$).

3.2. Behavioral data

From the final sample ($N = 60$), $n = 55$ participants were included in the behavioral analyses; $n = 5$ participants were excluded due to a low level of accuracy (i.e. <50 % of correct trials) in at least one of the experimental conditions. Outlying RTs (i.e., 2.5 *SD* from the mean) were removed. Descriptive statistics of RTs are reported in Table 2.

3.2.1. Reaction times (RTs)

A LMM with face age, emotional valence, sex, and PARQmother as independent variables was first performed. The model evidenced a main effect of face age ($F(1,255) = 12.1$, $p < .001$) and a main effect of emotional valence ($F(2,255) = 15.8$, $p < .001$). A significant interaction between face age and emotional valence also emerged ($F(2,255) = 10.7$, $p < .001$). Post-hoc comparisons revealed that participants displayed longer RTs in categorizing infant compared to adult faces (*adult vs. infant*: $t(255) = -3.5$, $p < .001$), and neutral compared to happy (*neutral vs. happy*: $t(255) = 5.5$, $p < .001$) and sad faces (*sad* vs. *neutral*: $t(255) = -3.7$, $p < .001$). Neutral infant faces were associated with the longest RTs (all $ps < 0.001$). A significant effect of PARQmother emerged ($F(1,51) = 8.1$, $p < .01$); those participants who felt more rejected by their own mother during childhood were overall slower in performing the task. A significant interaction effect between PARQmother and sex was detected ($F(1,51) = 4.2$, $p < .05$); males who felt more rejected by their own mother, compared to females, displayed a greater increase of RTs in recognizing all faces. Another LMM with face age, emotional valence, sex, and PARQfather as independent variables was performed. The model confirmed the effects found before. The main effect of PARQfather only approached statistical significance ($F(1,51) = 3.2$, $p = .08$). The results were confirmed by the check analyses (SM2).

3.3. Event-Related Potentials (ERPs)

From the final sample ($N = 60$), $n = 56$ participants were included in the ERP analyses; $n = 4$ participants were excluded due to excessive artifacts in the EEG data (>30 % of trials; $n = 2$) or technical problems in the signal acquisition ($n = 2$). The mean amplitude values of the N170 and LPP waves are reported in Table 3. The Grand Average waveforms of the N170 and LPP components are represented in Fig. 2 and Fig. 3, respectively.

3.3.1. N170 amplitude

A preliminary analysis was implemented to consider the effect of lateralization (right vs. left hemisphere) on the N170 amplitude; given that we found a non-significant effect of lateralization (SM1), we collapsed the N170 amplitude across hemispheres in the subsequent models. A LMM with the face age, emotional valence, sex, and PARQmother as independent variables was first implemented. The model evidenced a main effect of face age ($F(1,260) = 66.3$, $p < .001$); that is, infant faces elicited a larger N170 amplitude than adult faces (*adult vs. infant*: $t(260) = 8.1$, $p < .001$). An interaction effect between face age and sex emerged ($F(1,260) = 5.7$, $p = .02$); however, the post-hoc comparisons did not provide statistically significant results. The main effect of PARQmother was not significant. Another LMM with face age, emotional valence, sex, and PARQfather as independent variables was performed. The model confirmed the effects found before. A main effect of PARQfather ($F(1,52) = 5.1$, $p = .03$) and an interaction effect between PARQfather and face age ($F(1,260) = 4.8$, $p = .03$) emerged; that is, those participants who felt more rejected by their own father during childhood displayed a greater N170 amplitude in response to all faces. In particular, a greater level of perceived paternal rejection was associated with an increased N170 amplitude to infant versus adult faces. A three-way interaction effect between emotional valence, PARQfather and sex emerged ($F(2,260) = 3.2$, $p = .04$); females who felt more rejected by their own father, compared to males, had a stronger increase in the N170 amplitude in recognizing emotional (i.e., happy and sad) faces. However, despite the other results being confirmed by the check analyses (SM2), this effect was not corroborated as statistically significant.

3.3.2. LPP amplitude

A LMM with face age, emotional valence, sex, and PARQmother as independent variables was first performed. The model highlighted a main effect of emotional valence ($F(2,260) = 9.1$, $p < .001$) and an interaction effect between face age and emotional valence ($F(2,260) = 3.9$, $p = .02$). From the post-hoc comparisons, it was evidenced that sad faces elicited a larger LPP amplitude than happy (*sad vs. happy*: $t(260) = 4.2$; $p > .001$) and neutral faces (*sad vs. neutral*; $t(260) = 2.7$; $p = .02$). Adult sad faces elicited a larger LPP

Table 2
Mean RTs (SD) as a function of different conditions.

Experimental conditions	RTs (SD)
Infant happy	464.0 (172.5) ms
Infant neutral	529.0 (202.2) ms
Infant sad	463.7 (165.0) ms
Adult happy	442.9 (165.0) ms
Adult neutral	468.2 (169.6) ms
Adult sad	475.1 (170.2) ms

Table 3
Mean amplitude values (SD) of the N170 and LPP waves as a function of different experimental conditions.

Experimental conditions	N170 amplitude (SD)	LPP amplitude (SD)
Infant happy	−1.6 (3.5) μv	4.0 (2.5) μv
Infant neutral	−1.6 (3.5) μv	3.9 (2.6) μv
Infant sad	−1.6 (3.3) μv	4.3 (2.8) μv
Adult happy	−1.0 (3.1) μv	3.8 (2.3) μv
Adult neutral	−0.7 (3.1) μv	4.3 (2.6) μv
Adult sad	−1.0 (3.2) μv	4.3 (2.5) μv

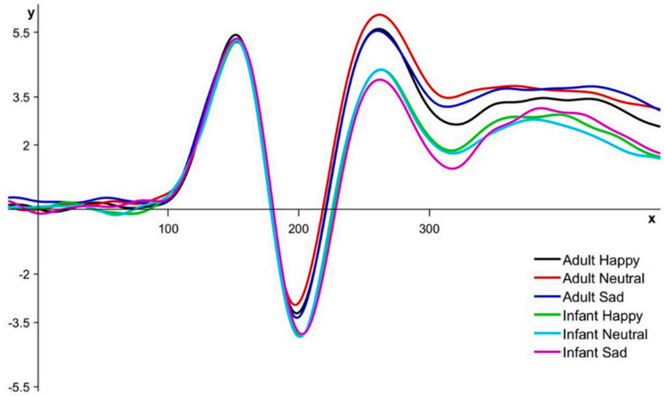

Fig. 2. Grand Average of the N170 component in different conditions. Amplitude (μV) is reported in the y axis. Latency (ms) is reported in the x axis.

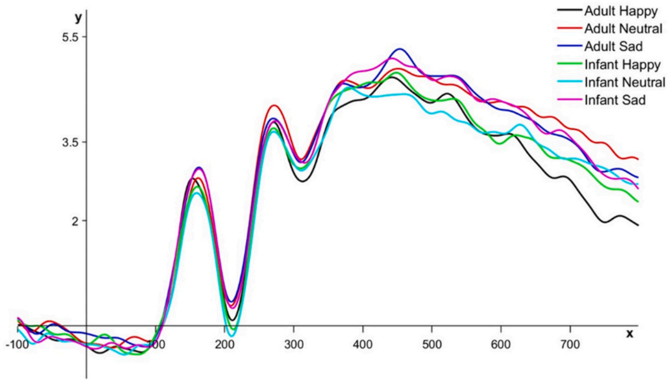

Fig. 3. Grand Average of the LPP component in different conditions. Amplitude (μV) is reported in the y axis. Latency (ms) is reported in the x axis.

amplitude than infant neutral faces (*adult sad vs. infant neutral*; $t(260) = 3.1$; $p = .04$). Infant sad faces elicited a larger LPP amplitude than infant neutral (*infant sad vs. infant neutral*; $t(260) = 3.6$; $p = .01$), adult happy (*infant sad vs. adult happy*; $t(260) = 3.5$; $p < .01$), and infant happy faces (*infant sad vs. infant happy*; $t(260) = 3.0$; $p = .04$). Another LMM with face age, emotional valence, sex, and PARQfather as independent variables was performed. The model confirmed the effects found before. A three-way interaction effect emerged between emotional valence, sex, and PARQfather ($F(2,260) = 5.9$, $p < .01$); that is, females who felt more rejected by their own father during childhood, compared to males, had a stronger decrease of the LPP amplitude in response to emotional (i.e., happy and sad) faces. The results were confirmed by the check analyses (SM2).

4. Discussion

Grounded in the IPARTheory (Rohner, 2021), the present study evidenced a rich pattern of associations between behavioral and neurophysiological responses to adult and infant faces and the perceived quality of care experiences from caregivers. In particular, while experiences of maternal rejection hindered the behavioral responses of adults in recognizing all faces, those who felt more rejected by their own father during childhood showed an enhanced N170 amplitude to infant faces. Therefore, an increased perception of paternal rejection was associated with a greater need for discrimination resources, in adults, at a very early stage of infant face processing. Moving beyond prior research confined to samples of women, we provided first evidence on how adults' sex can modulate the relationships between the quality of care experiences during childhood and ERP and behavioral responses to adult and infant faces.

4.1. Behavioral evidence

At the behavioral level, participants showed the worst performance in recognizing infant faces with neutral facial expressions. Therefore, those stimuli might be more difficult to categorize compared to other expressions characterized by more distinctive facial features (e.g., infant smile or cry; Lewinski, 2015). In addition, as the levels of the perceived maternal rejection increased, participants' RTs in categorizing faces increased. Unexpectedly, this effect was not specifically evidenced in response to infant faces; therefore, it seems that experiences of adverse maternal care hindered adults' ability to recognize facial expressions independently of the face age (i.e., adult vs. infant faces). It should be noted that previous research (e.g., Ma et al., 2017) did not include adult faces as a control condition, so whether the quality of early care had a specific contribution on the RTs to infant faces or to faces in general could not be ascertained. Differently, it has been widely assumed that experiences of a secure base support generally promote a flexible socio-emotional processing in individuals (Dykas & Cassidy, 2011). In addition to this evidence, males who felt more rejected by their own mother during childhood, compared to females, displayed longer RTs in recognizing all faces. Accordingly, a recent meta-analysis showed that, although the magnitude of the difference was not great, memories of a warm maternal care had stronger relations with the adult sons' psychological adjustment than with the one of adult daughters (Ali et al., 2015). Therefore, in some cases, males might display a greater developmental sensitivity to poor environmental experiences with their own mothers as compared to females.

4.2. Neurophysiological evidence

At the neurophysiological level, we confirmed that infant faces elicited a larger N170 amplitude compared to adult faces (Colasante et al., 2017; Proverbio et al., 2011). Thus, at very early stages of face processing, infant faces garnered heightened perceptual resources in adults when compared to other social stimuli. Differently, we did not find a larger LPP amplitude in response to infant than adult faces. Since non-parents might attribute less relevance to infant cues compared to parents (e.g., Proverbio et al., 2006), this effect might not be detected in our sample. In line with previous evidence (e.g., Weisman et al., 2012), a clearer difference in the LPP amplitude to infant versus adult faces may be more likely observed over a different group of electrodes compared to the one used here. In addition to this, according to the well-established evidence of a negativity bias in adults (e.g., Ito et al., 1998), we found that sad faces elicited a larger LPP amplitude compared to the other conditions.

Interestingly, we demonstrated that young adults who felt more rejected by their own father during childhood showed an enhanced N170 amplitude to infant faces, independently of the emotional valence of faces (e.g., see Fraedrich et al., 2010). Overall, this evidence might reflect a greater need for discrimination resources, at very early stages of infant face processing, for those individuals who felt more rejected by their own father during childhood. Differently, the same effect was not found for the quality of early maternal care. On this note, the importance of a warm paternal care on the adults' sensitivity to social stimuli has been evidenced before (Truzzi et al., 2018). Using the Parental Bonding Instrument (Parker, 1989), Truzzi et al. (2018) suggested that a history of appropriate paternal care in non-parent adults accentuated their sensitivity to human cry, partially determined by the individual genetic predisposition. Overall, our result provides additional empirical evidence on the importance of fathers for the offsprings' socio-emotional development (Leidy et al., 2013; Rodrigues et al., 2021); for the first time, we therefore demonstrated that it might be more demanding, for those individuals who felt more rejected by their own father during childhood, to process structural features of infant faces.

Regarding the modulating role of sex, we found that females who felt more rejected by their own father during childhood, compared to males, had a larger increase in the N170 amplitude, as well as a larger decrease in the LPP amplitude, in response to emotional faces. Therefore, females who perceived higher paternal rejection during childhood might struggle more in decoding the structural characteristics of emotional faces and allocate less sustained attention toward them. Accordingly, Sultana and Khaleque (2016) demonstrated that only the recollections of paternal (not maternal) acceptance made a significant and independent contribution on the adult daughters' psychological adjustment. Taken as a whole, our behavioral and neurophysiological findings might suggest that males and females can develop different developmental pathways in terms of social cue processing whether they had perceived rejection from their mother or father. However, since the modulatory effect of sex was not corroborated by the supplementary analyses (SM2) on the N170 amplitude, the results regarding the three-way interactions should be taken with caution and further investigated in future research.

5. Limitations and future directions

Some limitations of the study should be pointed out. First, our study was cross-sectional and partially relied on self-reported measures. Future studies could follow individuals longitudinally to explore the causal relationships among the variables and adopt a multi-method approach. Importantly, the experiment-wise alpha may be inflated in our study given the many models tested. Relatedly, the statistical analyses implemented here have been rather articulated and provided complex results in terms of interaction effects. For our findings, we were not able to calculate the effect sizes; even though LMMs have the advantage to capture multiple sources of random variations in the data (Westfall et al., 2014), there is no agreement on how to calculate effect sizes (Kumle et al., 2021). Beyond the ERP amplitudes, future studies may focus on the ERP latencies; integrating data on both the strength (amplitude) and speed (latency) of ERP responses may further the knowledge on the efficiency of neural processing. Another limitation of our work is that, during ERP preprocessing, we used longer epochs compared to those typically described in previous research; this procedure might introduce some noise in the data (Luck, 2014).

With respect to the PARQ, we acknowledge that this measure might not capture the experiences of individuals grown up in one-parent families or same-sex parent families, as it specifically asks about the quality of care experiences with one's own mother and father during childhood. To overcome this issue, the participants had the possibility to leave comments at the end of the survey, whether they had something more to say regarding their (possibly different) lived experiences. Of note, no participants in this study reported having a different type of family rather than the one composed by a mother and a father. However, a future advancement of the measure could provide a more inclusive assessment of early experiences of care, embracing the complexity of different family forms. In addition, as different experiences of care might be related to different attachment styles in adults, future studies might benefit from a combination of measures relating to both IPARTheory (Rohner, 2021) and Attachment Theory (Bowlby, 1969/1982). This methodological choice would also improve the comparability of findings with previous evidence on the topic (Fraedrich et al., 2010; Groh & Haydon, 2018; Leyh et al., 2016; Lowell et al., 2023).

Moreover, the present study possibly gave empirical support to the idea that mothers and fathers play distinctive roles in the child's developmental outcomes, especially regarding the processing of social stimuli like adult and infant faces. A task for future research would be to investigate further this evidence. In particular, the specific contribution of mothers and fathers can be read, in future studies, in the light of their roles in child rearing, not only in light of their sex (e.g., see Fagan et al., 2014). Therefore, care experiences with a mother or father may not be intrinsically different per se, but paternal or maternal roles, may they be taken by a mother or a father, could better relate with different characteristics of parents in caring for their children, leading to different outcomes in later children's development. This consideration should be importantly acknowledged in future studies.

Since adults' responses to infant signals are thought to organize caregiving behaviors (e.g., Vuoriainen et al., 2022), future research should examine the ecological validity of our findings, exploring whether alterations in face processing in individuals with adverse care experiences have some relevant implications for their caregiving practices. Eventually, we are aware that adults' responses to infant cues are complex and multiple factors might contribute to individual differences beyond the quality of care experiences with caregivers. So, it is essential for future research to consider multiple factors (e.g., the ones related to individuals' mental health) which might have a role in the adults' responses to infant cues. Importantly, enhancing the understanding of individual differences in infant cue processing might ultimately help to support parental and alloparental care under different circumstances.

6. Conclusion

The present work contributes to enhancing the IPARTheory's arguments by focusing on the behavioral and neurophysiological correlates of parental acceptance-rejection (Rohner & Khaleque, 2010). Evidence across multi-level indicators (RTs, ERPs) documented that being neglected during childhood might trigger perceptual changes in adults, hindering the elaboration of adult and infant faces at different levels. All in all, adult sensitivity to social stimuli like adult and infant faces might arise from the interaction of multiple factors; among these, the quality of early care experiences with caregivers continues to be demonstrated as relevant. Given these considerations, we emphasize the importance of implementing preventive interventions for young adults who had adverse caregiving experiences, potentially mitigating long-term consequences on the quality of parental or alloparental practices.

Fundings

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Micol Gemignani: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing, Software. **Simona de Falco:** Conceptualization, Project administration, Resources, Supervision, Writing – review & editing.

Declaration of Generative AI and AI-assisted technologies in the writing process

The authors did not use generative AI technologies for preparation of this work.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

We would like to thank all the study participants.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chiabu.2024.106874.

References

Abraham, E., & Feldman, R. (2018). The neurobiology of human allomaternal care; implications for fathering, coparenting, and children's social development. *Physiology & Behavior, 193*(Pt A), 25–34. https://doi.org/10.1016/j.physbeh.2017.12.034

Ali, S., Khaleque, A., & Rohner, R. P. (2015). Pancultural gender differences in the relation between perceived parental acceptance and psychological adjustment of children and adult offspring: A meta-analytic review of worldwide research. *Journal of Cross-Cultural Psychology, 46*(8), 1059–1080. https://doi.org/10.1177/0022022115597754

Arnett, J. J., Žukauskienė, R., & Sugimura, K. (2014). The new life stage of emerging adulthood at ages 18-29 years: Implications for mental health. *The lancet. Psychiatry, 1*(7), 569–576. https://doi.org/10.1016/S2215-0366(14)00080-7

Bataille, C. D., & Hyland, E. (2023). Involved fathering: How new dads are redefining fatherhood. *Personnel Review, 52*(4), 1010–1032. https://doi.org/10.1108/PR-06-2019-0295

Bates, D., Kliegl, R., Vasishth, S., & Baayen, H. (2015). Parsimonious mixed models. *arXiv preprint arXiv:1506.04967*.

Bem, S. L. (1974). The measurement of psychological androgynous. *Journal of Consulting and Clinical Psychology, 42*, 155–162. https://doi.org/10.1037/h0036215

Bick, J., Dozier, M., Bernard, K., Grasso, D., & Simons, R. (2013). Foster mother-infant bonding: Associations between foster mothers' oxytocin production, electrophysiological brain activity, feelings of commitment, and caregiving quality. *Child Development, 84*(3), 826–840. https://doi.org/10.1111/cdev.12008

Bowlby, J. (1969/1982). *Attachment and loss. Vol. 1: Attachment* (2nd ed.). Basic Book.

Colasante, T., Mossad, S. I., Dudek, J., & Haley, D. W. (2017). The special status of sad infant faces: Age and valence differences in adults' cortical face processing. *Social Cognitive and Affective Neuroscience, 12*(4), 586–595. https://doi.org/10.1093/scan/nsw166

Delorme, A., & Makeig, S. (2004). EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods, 134*(1), 9–21. https://doi.org/10.1016/j.jneumeth.2003.10.009

Doi, H., & Shinohara, K. (2012). Event-related potentials elicited in mothers by their own and unfamiliar infants' faces with crying and smiling expression. *Neuropsychologia, 50*(7), 1297–1307. https://doi.org/10.1016/j.neuropsychologia.2012.02.013

Dudek, J., & Haley, D. W. (2020). Attention bias to infant faces in pregnant women predicts maternal sensitivity. *Biological Psychology, 153*, Article 107890. https://doi.org/10.1016/j.biopsycho.2020.107890

Dykas, M. J., & Cassidy, J. (2011). Attachment and the processing of social information across the life span: Theory and evidence. *Psychological Bulletin, 137*(1), 19–46. https://doi.org/10.1037/A0021367

Eimer, M. (2011). The face-sensitive N170 component of the event-related brain potential. *The Oxford handbook of face perception, 28*, 329–344.

Fagan, J., Day, R., Lamb, M. E., & Cabrera, N. J. (2014). Should researchers conceptualize differently the dimensions of parenting for fathers and mothers? *Journal of Family Theory & Review, 6*(4), 390–405. https://doi.org/10.1111/jftr.12044

Fraedrich, E. M., Lakatos, K., & Spangler, G. (2010). Brain activity during emotion perception: The role of attachment representation. *Attachment & Human Development, 12*(3), 231–248. https://doi.org/10.1080/14616731003759724

Gemignani, M., Giannotti, M., & de Falco, S. (2024). The perceived quality of maternal care during childhood shapes attentional bias to infant faces in parents and nonparents. *Journal of family psychology : JFP : journal of the Division of Family Psychology of the American Psychological Association (Division 43)*. https://doi.org/10.1037/fam0001198. Advance online publication.

Gemignani, M., Giannotti, M., Rigo, P., & de Falco, S. (2024). Attentional bias to infant faces might be associated with previous care experiences and involvement in childcare in same-sex mothers. *International journal of clinical and health psychology : IJCHP, 24*(1), Article 100419. https://doi.org/10.1016/j.ijchp.2023.100419

Gemignani, M., Giannotti, M., Schmalz, X., Rigo, P., & De Falco, S. (2022). Attentional prioritization of infant faces in parents: The influence of parents' experiences of care. *International Journal of Environmental Research and Public Health, 20*(1), 527. https://doi.org/10.3390/ijerph20010527

Glasper, E. R., Kenkel, W. M., Bick, J., & Rilling, J. K. (2019). More than just mothers: The neurobiological and neuroendocrine underpinnings of allomaternal caregiving. *Frontiers in Neuroendocrinology, 53*, Article 100741. https://doi.org/10.1016/j.yfrne.2019.02.005

Grasso, D. J., Moser, J. S., Dozier, M., & Simons, R. (2009). ERP correlates of attention allocation in mothers' processing faces of their children. *Biological Psychology, 81*, 95–102. https://doi.org/10.1016/j.biopsycho.2009.03.001

Groh, A. M., & Haydon, K. C. (2018). Mothers' neural and behavioral responses to their infants' distress cues: The role of secure base script knowledge. *Psychological Science, 29*(2), 242–253. https://doi.org/10.1177/0956797617730320

Guerra, P., Vico, C., Campagnoli, R., Sánchez, A., Anllo-Vento, L., & Vila, J. (2012). Affective processing of loved familiar faces: Integrating central and peripheral electrophysiological measures. *International Journal of Psychophysiology, 85*(1), 79–87. https://doi.org/10.1016/j.ijpsycho.2011.06.004

Hajcak, G., & Foti, D. (2020). Significance?... Significance! Empirical, methodological, and theoretical connections between the late positive potential and P300 as neural responses to stimulus significance: An integrative review. *Psychophysiology, 57*(7), 1–15. https://doi.org/10.1111/psyp.13570

Ito, T. A., Larsen, J. T., Smith, N. K., & Cacioppo, J. T. (1998). Negative information weighs more heavily on the brain: The negativity bias in evaluative categorizations. *Journal of Personality and Social Psychology, 75*(4), 887–900. https://doi.org/10.1037//0022-3514.75.4.887

Khaleque, A., & Rohner, R. P. (2002). Perceived parental acceptance-rejection and psychological adjustment: A meta-analysis of cross-cultural and intracultural studies. *Journal of Marriage and Family, 64*, 54–64.

Khaleque, A., & Rohner, R. P. (2012). Pancultural associations between perceived parental acceptance and psychological adjustment of children and adults a meta-analytic review of worldwide research. *Journal of Cross-Cultural Psychology, 43*, 784–800.

Kumle, L., Võ, M. L., & Draschkow, D. (2021). Estimating power in (generalized) linear mixed models: An open introduction and tutorial in R. *Behavior Research Methods, 53*(6), 2528–2543. https://doi.org/10.3758/s13428-021-01546-0

Kuzava, S., Frost, A., Perrone, L., Kang, E., Lindhiem, O., & Bernard, K. (2020). Adult processing of child emotional expressions: A meta-analysis of ERP studies. *Developmental Psychology, 56*(6), 1170–1190. https://doi.org/10.1037/dev0000928

Kuzava, S., Nissim, G., Frost, A., Nelson, B., & Bernard, K. (2019). Latent profiles of maternal neural response to infant emotional stimuli: Associations with maternal sensitivity. *Biological Psychology, 143*, 113–120. https://doi.org/10.1016/j.biopsycho.2019.02.009

Leidy, M. S., Schofield, T. J., & Parke, R. D. (2013). Fathers' contributions to children's social development. In N. J. Cabrera, & C. S. Tamis-LeMonda (Eds.), *Handbook of father involvement: Multidisciplinary perspectives* (2nd ed., pp. 151–167). Routledge/Taylor & Francis Group.

Lewinski, P. (2015). Automated facial coding software outperforms people in recognizing neutral faces as neutral from standardized datasets. *Frontiers in Psychology, 6*, 1386. https://doi.org/10.3389/fpsyg.2015.01386

Leyh, R., Heinisch, C., Behringer, J., Reiner, I., & Spangler, G. (2016). Maternal attachment representation and neurophysiological processing during the perception of infants' emotional expressions. *PLoS One, 11*(2), Article e0147294. https://doi.org/10.1371/journal.pone.0147294

Lopez-Calderon, J., & Luck, S. J. (2014). ERPLAB: An open-source toolbox for the analysis of event-related potentials. *Frontiers in Human Neuroscience, 8*, 213. https://doi.org/10.3389/fnhum.2014.00213

Lowell, A. F., Dell, J., Potenza, M. N., Strathearn, L., Mayes, L. C., & Rutherford, H. J. (2023). Adult attachment is related to maternal neural response to infant cues: An ERP study. *Attachment & Human Development, 25*(1), 71–88. https://doi.org/10.1080/14616734.2021.1880057

Luck, S. J. (2014). *An introduction to the event-related potential technique*. MIT press.

Lundqvist, D., Flykt, A., & Öhman, A. (1998). *The Karolinska Directed Emotional Faces - KDEF, CD ROM from Department of Clinical Neuroscience, Psychology section, Karolinska Institutet*. ISBN 91-630-7164-9.

Ma, Y., Ran, G., Chen, X., Ma, H., & Hu, N. (2017). Adult attachment styles associated with brain activity in response to infant faces in nulliparous women: An event-related potentials study. *Frontiers in Psychology, 8*, 627. https://doi.org/10.3389/fpsyg.2017.00627

Maack, J. K., Bohne, A., Nordahl, D., Livsdatter, L., Lindahl, Å. A., Øvervoll, M., … Pfuhl, G. (2017). The Tromso Infant Faces Database (TIF): Development, validation and application to assess parenting experience on clarity and intensity ratings. *Frontiers in Psychology, 8*, 409. https://doi.org/10.3389/fpsyg.2017.00409

Malak, S. M., Crowley, M. J., Mayes, L. C., & Rutherford, H. J. (2015). Maternal anxiety and neural responses to infant faces. *Journal of Affective Disorders, 172*, 324–330. https://doi.org/10.1016/j.jad.2014.10.013

Mathôt, S., Schreij, D., & Theeuwes, J. (2012). OpenSesame: An open-source, graphical experiment builder for the social sciences. *Behavior Research Methods, 44*(2), 314–324. https://doi.org/10.3758/s13428-011-0168-7

Maupin, A. N., Rutherford, H. J., Landi, N., Potenza, M. N., & Mayes, L. C. (2019). Investigating the association between parity and the maternal neural response to infant cues. *Social Neuroscience, 14*(2), 214–225. https://doi.org/10.1080/17470919.2017.1422276

Noll, L. K., Mayes, L. C., & Rutherford, H. J. (2012). Investigating the impact of parental status and depression symptoms on the early perceptual coding of infant faces: An event-related potential study. *Social Neuroscience, 7*(5), 525–536. https://doi.org/10.1080/17470919.2012.672457

Olofsson, J. K., Nordin, S., Sequeira, H., & Polich, J. (2008). Affective picture processing: An integrative review of ERP findings. *Biological Psychology, 77*(3), 247–265. https://doi.org/10.1016/j.biopsycho.2007.11.006

Parker, G. (1989). The parental bonding instrument: Psychometric properties reviewed. *Psychiatric Developments, 7*(4), 317–335.

Peltola, M. J., Strathearn, L., & Puura, K. (2018). Oxytocin promotes face-sensitive neural responses to infant and adult faces in mothers. *Psychoneuroendocrinology, 91*, 261–270. https://doi.org/10.1016/j.psyneuen.2018.02.012

Peltola, M. J., Yrttiaho, S., Puura, K., Proverbio, A. M., Mononen, N., Lehtimäki, T., & Leppänen, J. M. (2014). Motherhood and oxytocin receptor genetic variation are associated with selective changes in electrocortical responses to infant facial expressions. *Emotion, 14*(3), 469. https://doi.org/10.1037/a0035959

Peoples, S. G., Lowell, A. F., Bunderson, M., Bartz, C., Yip, S. W., & Rutherford, H. J. (2022). The effects of prenatal stress on neural responses to infant cries in expectant mothers and fathers. *Developmental Psychobiology, 64*(5), Article e22280. https://doi.org/10.1002/dev.22280

Pion-Tonachini, L., Kreutz-Delgado, K., & Makeig, S. (2019). ICLabel: An automated electroencephalographic independent component classifier, dataset, and website. *NeuroImage, 198*, 181–197. https://doi.org/10.1016/j.neuroimage.2019.05.026

Proverbio, A. M., Brignone, V., Matarazzo, S., Del Zotto, M., & Zani, A. (2006). Gender and parental status affect the visual cortical response to infant facial expression. *Neuropsychologia, 44*(14), 2987–2999. https://doi.org/10.1016/j.neuropsychologia.2006.06.015

Proverbio, A. M., Riva, F., Zani, A., & Martin, E. (2011). Is it a baby? Perceived age affects brain processing of faces differently in women and men. *Journal of Cognitive Neuroscience, 23*(11), 3197–3208. https://doi.org/10.1162/jocn_a_00041

Ripoll-Núñez, K., & Carrillo, S. (2016). Adult intimate relationships: Linkages between interpersonal acceptance-rejection theory and adult attachment theory. *Online Readings in Psychology and Culture, 6*(2), 4.

Rodrigo, M., León, I., Quiñones, I., Lage, A., Byrne, S., & Bobes, M. (2011). Brain and personality bases of insensitivity to infant cues in neglectful mothers: An event-related potential study. *Development and Psychopathology, 23*(1), 163–176. https://doi.org/10.1017/S0954579410000714

Rodrigues, M., Sokolovic, N., Madigan, S., Luo, Y., Silva, V., Misra, S., & Jenkins, J. (2021). Paternal sensitivity and children's cognitive and socioemotional outcomes: A meta-analytic review. *Child Development, 92*(2), 554–577. https://doi.org/10.1111/cdev.13545

Rohner, R. P. (2004). The parental "acceptance-rejection syndrome": Universal correlates of perceived rejection. *The American Psychologist, 59*(8), 830–840. https://doi.org/10.1037/0003-066X.59.8.830

Rohner, R. P. (2005). Parental Acceptance-Rejection Questionnaire (PARQ): Test manual. In R. P. Rohner, & A. Khaleque (Eds.), *Handbook for the study of parental acceptance and rejection* (4th ed., pp. 43–106). Storrs, CT: Rohner Research Publications.

Rohner, R. P. (2021). Introduction to Interpersonal Acceptance-Rejection Theory (IPARTheory) and evidence. *Online Readings in Psychology and Culture, 6*(1).

Rohner, R. P., & Khaleque, A. (2010). Testing central postulates of parental acceptance-rejection theory (PARTheory): A meta-analysis of cross-cultural studies. *Journal of Family Theory & Review, 2*(1), 73–87. https://doi.org/10.1111/j.1756-2589.2010.00040.x

Rohner, R. P., Khaleque, A., & Cournoyer, D. E. (2012). Introduction to parental acceptance-rejection theory, methods, evidence, and implications. *Journal of Family Theory & Review, 2*(1), 73–87.

Rossion, B., & Jacques, C. (2008). Does physical interstimulus variance account for early electrophysiological face sensitive responses in the human brain? Ten lessons on the N170. *Neuroimage, 39*(4), 1959–1979. https://doi.org/10.1016/j.neuroimage.2007.10.011

Rutherford, H. J., Bunderson, M., Bartz, C., Haitsuka, H., Meins, E., Groh, A. M., & Milligan, K. (2021). Imagining the baby: Neural reactivity to infant distress and mind-mindedness in expectant parents. *Biological Psychology, 161*, Article 108057. https://doi.org/10.1016/j.biopsycho.2021.108057

Rutherford, H. J., Byrne, S. P., Austin, G. M., Lee, J. D., Crowley, M. J., & Mayes, L. C. (2017). Anxiety and neural responses to infant and adult faces during pregnancy. *Biological Psychology, 125*(2017), 115–120. https://doi.org/10.1016/j.biopsycho.2017.03.002

Rutherford, H. J., Maupin, A. N., Landi, N., Potenza, M. N., & Mayes, L. C. (2017a). Current tobacco-smoking and neural responses to infant cues in mothers. *Parenting, 17*(1), 1–10. https://doi.org/10.1080/15295192.2017.1262176

Rutherford, H. J. V., Maupin, A. N., Landi, N., Potenza, M. N., & Mayes, L. C. (2017c). Parental reflective functioning and the neural correlates of processing infant affective cues. *Social Neuroscience, 12*(5), 519–529. https://doi.org/10.1080/17470919.2016.1193559

Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2004). The selective processing of briefly presented affective pictures: An ERP analysis. *Psychophysiology, 41*(3), 441–449. https://doi.org/10.1111/j.1469-8986.2004.00174.x

Senese, V. P., Bacchini, D., Miranda, M. C., Aurino, C., Somma, F., Amato, G., & Rohner, R. P. (2016). The adult parental acceptance–rejection questionnaire: A cross-cultural comparison of Italian and American short forms. *Parenting, 16*(4), 219–236. https://doi.org/10.1080/15295192.2016.1180943

Senese, V. P., Miranda, M. C., De Falco, S., Venuti, P., & Bornstein, M. H. (2018). How becoming a mother shapes implicit and explicit responses to infant cues. *Developmental Psychobiology, 60*(8), 950–962. https://doi.org/10.1002/dev.21772

Seyedmousavi, P., Khoshroo, S., Memarian, M., Ghanbari, S., & Rohner, R. P. (2022). Memories of parental rejection and fear of intimacy: the role of psychological maladjustment, interpersonal anxiety, and rejection by an intimate Partner. *Current Psychology*, 1–9. https://doi.org/10.1007/s12144-022-04160-1

Spangler, G., Maier, U., Geserick, B., & von Wahlert, A. (2010). The influence of attachment representation on parental perception and interpretation of infant emotions: A multilevel approach. *Developmental Psychobiology, 52*(5), 411–423. https://doi.org/10.1002/dev.20441

Sultana, S., & Khaleque, A. (2016). Differential effects of perceived maternal and paternal acceptance on male and female adult offspring's psychological adjustment. *Gender Issues, 33*, 42–54. https://doi.org/10.1007/s12147-015-9147-0

Truzzi, A., Poquérusse, J., Setoh, P., Shinohara, K., Bornstein, M. H., & Esposito, G. (2018). Oxytocin receptor gene polymorphisms (rs53576) and early paternal care sensitize males to distressing female vocalizations. *Developmental Psychobiology, 60*(3), 333–339.

Vuoriainen, E., Bakermans-Kranenburg, M. J., Huffmeijer, R., van IJzendoorn, M. H., & Peltola, M. J. (2022). Processing children's faces in the parental brain: A meta-analysis of ERP studies. *Neuroscience and Biobehavioral Reviews, 136*, Article 104604. https://doi.org/10.1016/j.neubiorev.2022.104604

Waller, C., Wittfoth, M., Fritzsche, K., Timm, L., Wittfoth-Schardt, D., Rottler, E., Heinrichs, M., Buchheim, A., Kiefer, M., & Gündel, H. (2015). Attachment representation modulates oxytocin effects on the processing of own-child faces in fathers. *Psychoneuroendocrinology, 62*, 27–35. https://doi.org/10.1016/j.psyneuen.2015.07.003

Weisman, O., Feldman, R., & Goldstein, A. (2012). Parental and romantic attachment shape brain processing of infant cues. *Biological Psychology, 89*(3), 533–538. https://doi.org/10.1016/j.biopsycho.2011.11.008

Westfall, J., Kenny, D. A., & Judd, C. M. (2014). Statistical power and optimal design in experiments in which samples of participants respond to samples of stimuli. *Journal of Experimental Psychology. General, 143*(5), 2020–2045. https://doi.org/10.1037/xge0000014