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Facial mimicry to infant and adult emotions in mothers and non-mothers

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Abstract

A key aspect of parent–infant interaction is parental mirroring of infant emotions through facial mimicry, the automatic imitation of observed facial expressions. Facial mimicry can be measured using facial electromyography (EMG) and has been associated with empathic abilities, such as recognizing others' emotions. Currently, there is no research investigating how such empathy-related processes might change during the transition to parenthood. In this study, we compared first-time mothers of young infants and non-mothers in their physiological responses in two facial muscle areas (corrugator supercilii and zygomaticus major) to dynamic emotional infant and adult faces. In addition, we examined whether the EMG responses are associated with salivary testosterone levels. Participants performed an emotion recognition task with dynamic infant and adult emotional expressions changing between happy and distressed expressions while facial mimicry was measured with EMG. Mothers showed a more pronounced zygomaticus response specifically to smiling infant faces, and a greater corrugator response to faces changing to distress, regardless of stimulus age. Non-mothers' zygomaticus response to infant smiles was inversely associated with testosterone level. No other correlations between testosterone and EMG responses were found. These results indicate that new mothers may show heightened affective empathic reactivity especially to infant emotions.

KEYWORDS
emotion recognition, empathy, facial expressions, parenting, testosterone

1 | INTRODUCTION

The face conveys a great deal of emotional and social information. Considering parenting, key components of sensitive caregiving include recognizing, interpreting, and reacting promptly to infants' facial and vocal emotional signals.[1] One way for the parent to attune to the infant's emotions might be through facial mimicry, the automatic imitation of observed facial expressions of the infant activated in the parent.[2,3] Parental mirroring of infant emotions through facial mimicry, prosody, and other cues may help the infant to differentiate between emotions, which in turn supports development of emotion regulation abilities.[3–5] Although parental mirroring of infant emotions seems to be important for parent–infant interaction,[6] there is no research investigating whether this component of parental responsivity changes during the transition to parenthood. In this study, we compare first-time mothers of young infants and non-mothers

(i.e., women without children) in their facial mimicry in response to dynamic infant and adult emotional facial expressions. In addition, we examine whether such responses are associated with salivary testosterone levels and self-reported empathy.

Automatic and unconscious reactions to emotional stimuli can be measured with facial electromyography (EMG). Negative emotional stimuli (e.g., angry faces) have been found to increase *corrugator supercilii* (frowning) activation whereas positive emotional stimuli (e.g., happy faces) activate the *zygomaticus major* muscle that is responsible for lifting the corners of the mouth while smiling.[7] EMG is highly sensitive in detecting subtle facial responses when participants are passively viewing emotions, even when they are trying to conceal their expressions.[8]

In previous studies, facial muscle activation has been associated with emotion recognition abilities and empathic traits. In one study participants who had their facial mimicry immobilized by holding a pen horizontally between their lips and teeth were slower in detecting the offset of an emotion on the target face than participants who had their whole facial muscle latitude intact.[9] People high in affective empathy have also been shown to react with greater activity in muscles corresponding to negative and positive emotions when watching angry or happy faces.[10,11] In adolescents, facial EMG responses to emotional film clips were related to state affective empathy measured with computerized tasks.[12] Additionally, corrugator responsiveness to sad stimuli has been associated with self-reported affective empathy (positively in adolescent girls and negatively in boys) but not with self-reported cognitive empathy.[12] These results can be interpreted in light of the Facial Feedback Hypothesis, which proposes that the feedback signals to the brain from facial muscles involved in emotion expressions impact differentiation and recognition of emotions (e.g.,[13,14]; for meta-analysis see[15]). Relatedly, patients with central facial paresis following a stroke have been found to perform less accurately in facial emotion recognition tasks than healthy controls.[16]

Research investigating whether the automatic facial responses to emotion cues change during the transition to parenthood is scarce. Bjertrup et al.[17] measured facial and autonomic responses to infant stimuli in mothers and non-mothers with automated facial analysis software and found that mothers compared to non-mothers displayed a more positive expression while watching a video of child laughter. In addition, mothers expressed higher arousal, measured by skin conductance responses to emotional infant videos, and their gaze was longer fixated on the video.[17] Aligned with these findings, there is some evidence that infant faces might capture attention more strongly in mothers than in non-mothers when infant faces are used as distractors in a simple attention probe task.[18,19] Seemingly in contrast, one study showed that mothers needed more time to recognize child emotions than non-mothers when shown a short video of an expression morphing on a target face.[20] The authors suggested that the finding could be due to task interference: mothers may react with a greater empathic response to child emotions, which may distract their attention.[20] No previous studies have used EMG to measure differences in empathic responses to infant emotions in parents and non-parents.

Studies comparing brain responses in parents and non-parents have also associated parity with brain activation when perceiving infant stimuli. In EEG studies, the amplitude of the face-sensitive N170 event-related potential (ERP) component in response to viewing infant faces has been found to be larger in parents than in non-parents, which might indicate that parents' facial encoding system is more sensitized to infantile features.[21] Similar results have been found in fMRI studies. Using infant auditory emotional stimuli, Seifritz et al.[22] found that parents responded more strongly to infant crying whereas non-parents showed heightened reactivity to infant laughter, and a meta-analysis focusing on infant cries similarly reported greater parental activation in a corticolimbic sensorimotor integration network, potentially supporting enhanced processing of and motivation to respond to infant crying.[23] In addition, parity might also have an effect when comparing the difference between responses to positive and negative emotions in infants: Bjertrup et al.[17] found that mothers had a more pronounced difference in their dorsolateral prefrontal cortex and left middle temporal gyrus activity to distressed versus happy infant faces than non-mothers.

One factor potentially impacting differential neural and behavioral responses to infant stimuli of parents and non-parents may be the hormonal levels associated with the transition to parenthood.[24] Especially, the gonadal hormone testosterone has been associated with motivation and attention towards infant stimuli,[25–27] and with empathy in a context-dependent manner: Zilioli et al.[28] reported associations with self-reported empathy in men only, and only when basal cortisol levels were taken into account. However, the results linking testosterone directly to facial EMG responses have been inconsistent. One experimental study with female participants found that testosterone administration was related to decreased facial mimicry towards happy and angry facial expressions,[29] whereas another study showed that when women were presented with pictures of children in distressing environments, testosterone administration led to stronger corrugator EMG responses.[30] Exogenous testosterone effects might, however, differ drastically from natural hormonal variation and functioning in the body. This might explain null results in studies with endogenous gonadal hormone assessment: in one study, facial mimicry to pictures of people in emotionally charged situations was not correlated with salivary estradiol, testosterone, or progesterone levels in a sample of free-cycling women, women using oral contraceptives, and men.[31] These differences might be due to the different stimuli and context of the studies (experimental vs. correlational), and therefore the association between testosterone and empathic reactions to infant emotion signals needs to be further examined.

Our study compared first-time mothers' and non-mothers' facial muscle responses to infant and adult facial expressions and explored whether EMG responses to emotional faces are associated with salivary testosterone levels. First, we aimed to test whether mothers and non-mothers differ in their automatic facial muscle responses when viewing videos of dynamic infant and adult emotional faces (i.e., expressions changing from smiling to distressed or vice versa). We expected mothers to show stronger activation than non-mothers in zygomaticus and corrugator muscles when viewing smiling and

distressed infant faces, respectively, but not when viewing adult faces with smiling and sad expressions, thus indicating an interaction between parity and stimulus face age. Second, via reaction times, we compared mothers and non-mothers in their ability to recognize emotion offset from the same dynamic videos showing changes in emotional expression. Third, in exploratory analyses, we investigated whether the EMG responses are associated with salivary testosterone levels. Finally, we explored whether self-reported trait empathy is related to facial muscle responses.

2 | METHODS

2.1 | Participants

The participants were part of the TransParent project, which investigates changes in processing infant cues during the transition to parenthood. Participants ($N = 116$) were 62 non-mothers ($M_{age} = 26.1$, $SD = 3.4$) and 54 first-time mothers ($M_{age} = 29.9$, $SD = 3.0$). Mothers were significantly older than non-mothers, $t(114) = -6.24$, $p < 0.001$. Inclusion criteria were living with a partner in a relationship lasting longer than 6 months (Mothers: $M = 6.5$ years, $SD = 3.3$; Non-mothers: $M = 4.6$ years, $SD = 3.5$; $t(109) = 2.83$, $p = 0.006$), fluent skills in Finnish language, and age 22–37 years. In addition, mothers had to have a first child who was approximately 6 months old ($M = 7.2$, $SD = 1.5$), and non-mothers were required to have no children of their own or their partner's. The majority of mothers (82%) were breastfeeding their infants at the time. Hormonal birth control usage was more common for non-mothers (63%) than mothers (20%). Groups did not differ in their educational level (years of education; Mothers: $M = 17.0$ years, $SD = 2.3$; Non-mothers: $M = 16.3$ years, $SD = 2.0$; $t(109) = 1.80$, $p = 0.075$), but mothers had a higher annual household income ($\chi^2(5) = 33.14$, $p < 0.001$; for more details of the study sample, see[27,32]).

Mothers were recruited by invitation letters sent based on contact information of local primiparous families obtained from the Digital and Population Data Services Agency. Non-mothers were recruited through university email lists. One participant from the original non-mother group ($N = 63$) was excluded due to technical issues with the EMG task, making the final sample size 116 participants. As a reward for participation, participants received one movie ticket and course credit when applicable. The study protocol was approved by the Ethics Committee of the Tampere Region.

2.2 | Procedure

The participants were called to schedule their visit in the lab during the luteal phase of their menstrual cycle. If the participants were unable to report the phases of their cycle, the visit was scheduled at a random time. The laboratory visit took approximately 1.5 h during which the participants performed five computerized tasks, interacted with an infant simulator,[32] provided two saliva samples, and completed several questionnaires. The task presented in this article took place in the middle part of the laboratory visit, approximately 40 min after arriving at the laboratory and 35 min after providing the first saliva sample and approximately 5 min after providing the second saliva sample. Hormonal levels in this sample have been previously reported in Sinisalo et al.[32] and another computer task has been reported in Sinisalo et al.[27]

2.3 | Stimuli and task

Participants were presented with a dynamic facial expression task adapted from Korb et al.[33] with adult and infant face stimuli. The stimulus presentation included 6000-ms videos of faces showing emotional expressions changing from happy to distress or vice versa (Figure 1). The stimuli included eight adult and eight infant (50% male, 50% female) individual models. The infant stimuli were extracted from videos of 7-month-old infants collected by Strathearn et al.[34] The pictures of emotional facial expressions were extracted from two different situations: the happy expressions from videos recorded during playful interaction and the distressed faces when the infant was left alone for a short period of time. Adult faces were acquired from the NimStim Set of Facial Expressions, depicting open mouth happy and sad facial expressions (http://www.macbrain.org/resources.html).[35] We used WebMorph (https://debruine.github.io/project/webmorph/) to combine pictures of faces to a continuous video. In WebMorph, markers for facial features (i.e., eyes, mouth, face outline) were added to the stimulus faces and the videos were created based on these markers. Face halves were mirrored to increase facial symmetry and thereby reduce potential distortions caused by blending two facial expressions. A black background mask was added to each stimulus and the stimuli were matched for brightness. From each model the original happy and distressed faces were the opposite ends of the dynamic emotion expression. The expression change was created by blending the opposite expression (e.g., happy) with the initial expression (distress) in one-percent steps, which created 100 images which were then converted to an .avi video file. In the video file, each image was presented for 50 ms, creating a 5000-ms dynamic expression change that was followed by the final image (i.e., 100% happy or distress face) presented for 1000 ms. Two different videos were created for each of the 16 models: one shifting from happy to distress and one from distress to happy.

The task was presented with E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). The videos were shown on a black background. After each trial the screen was black for 2000 ms, followed by a fixation cross that was shown for 1000 ms before the next trial. The stimuli were presented in separate blocks of adult or infant faces. Four blocks (two blocks with adult faces and two blocks with infant faces) were presented, resulting in a total of 64 trials. One block consisted of 16 trials: eight trials from eight individual face models with expression shifting from smiling to distressed and eight trials shifting the other way. This resulted in a total of 32 adult trials and 32 infant trials. The presentation order of adult and infant blocks was

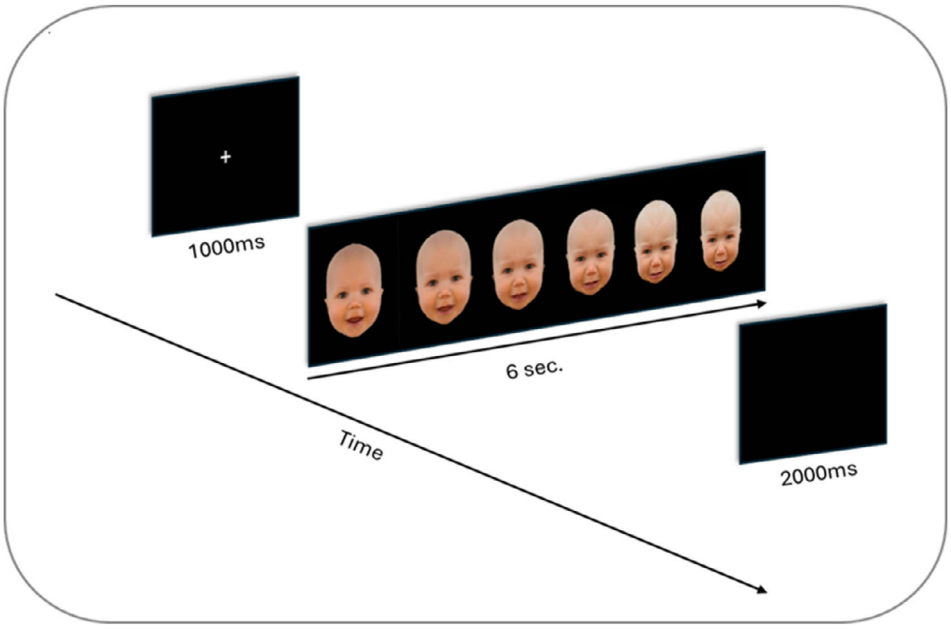

FIGURE 1 Example of the task and stimuli video used. The expression change is depicted here in one second intervals.

balanced between participants. The task duration was approximately 10 min.

During the task, the participants were instructed to press the space bar as quickly and accurately as possible when they evaluated that the expression displayed in the beginning of the video was no longer visible on the face. In the beginning of the task, participants were presented with three practice rounds. The key presses were used as a reaction time variable indicating the perceived offset of the initial emotion.

2.4 | Measures

2.4.1 | Acquisition and analysis of physiological data

Facial responses to dynamic emotion expressions during the emotion recognition task were measured with EMG from two facial muscles (corrugator supercilii and zygomaticus major). EMG responses were measured with 4-mm bipolar Ag/AgCl electrodes. To enhance conductivity, electrolyte gel was applied to the electrodes. The electrode pairs were then attached to disinfected skin by placing them 1 cm apart from each other on the left side of the face in the cheek (zygomaticus major) and brow regions (corrugator supercilii) according to the placement guidelines by Fridlund and Cacioppo.[36] In addition, a ground electrode was attached to the middle of the forehead below the hairline. The signal was amplified with a QuickAmp amplifier using a 1000-Hz sampling frequency and recorded with BrainVision Recorder software (Brain Products GmbH). The participants were told that the electrodes were measuring skin temperature instead of facial muscle activity to not draw their attention to the measurement of facial expressions. The functioning of the electrodes was tested by asking the participants to lift their eyebrows and the corners of their mouths.

Offline, using BrainVision Analyzer 2.1 software, the EMG signal was filtered with a 28–249 Hz bandpass filter, rectified, and segmented into 7000-ms epochs consisting of a 1000-ms pre-stimulus baseline and the 6000-ms stimulus presentation trial. The signal around each trial's baseline was visually inspected for artifacts (e.g., eye blinks or excessive muscle activity). As a result, an average of 10% of the trials were rejected. Mothers had more excluded trials with both muscles (zygomaticus: 8% vs. 6%; corrugator: 17% vs. 9%) than non-mothers, but the number of accepted trials was not correlated with the EMG responses in either group. The accepted epochs were then further segmented into a 500-ms pre-stimulus baseline bin and six 1000-ms bins after stimulus onset resulting in a total of seven time bins of which the six post-stimulus time bins were used for statistical analysis. The EMG signal was averaged across the baseline and all accepted post-stimulus trials within each participant, emotion direction (happy—distress or distress—happy), stimulus age (adult/infant), and time bin. The average values were then standardized within participants and muscle sites to reduce the influence of extreme values. Finally, using the standardized data, the baseline values (average activity during the 500-ms pre-stimulus period) were subtracted from each 1000-ms average value within each trial to calculate the muscle responses.

2.4.2 | Reaction times

During the task, participants were asked to mark the emotion offset, that is, the point at which they thought that the original emotion of the stimulus was no longer visible on the stimulus face (see,[33] for a similar offset task). Responses were made by pressing the space bar on a keyboard. Despite the participants pressing the space bar, the whole six-second video was shown to measure the facial responses. No feedback from the key press was provided to the participant, to

not intervene with the EMG measurement. Reaction times were measured as milliseconds from the trial onset.

2.4.3 | Testosterone

Testosterone levels were measured with saliva samples that were collected with a chewable Salivette® (Sarstedt, Nümbrecht, Germany) polypropylene swab. The participants were asked to chew the swab for a minute and not touch it with their hands or lips to avoid any contagion. After 1 min, participants placed the swab in a polyethylene container without touching the swab with their hands. The swabs were stored in a commercial freezer (−20 to −30°C) for a maximum of 7 days before they were moved in dry ice to a liquid nitrogen freezer (−80°C). During the lab visit, the participants gave two saliva samples, but only the first one (baseline) was used here to explore the association between testosterone and the EMG responses. Saliva samples were analyzed in the Finnish Institute of Occupational Health (Helsinki, Finland) with enzyme immunoassay for the quantitative determination of free testosterone in saliva (EIA, IBL International, RE52631). The measuring range of the method is 10–900 pg/mL. The coefficients of variation percent for intra-assay and interassay of the method were 6% and 9%, respectively. The analysis was successful for 97% of both samples.

2.4.4 | Self-reported empathy

Self-reported empathy was measured with the Interpersonal Reactivity Index questionnaire.[37] The questionnaire consists of 28 items, which are divided into four scales, each containing seven items. Participants are asked to answer with a 5-point Likert scale from "Does not describe me very well" to "Describes me very well". The four scales calculated from the questionnaire are (1) Empathic concern (e.g., "*I am often quite touched by things that I see happen.*", Cronbach's $\alpha = 0.77$), (2) Fantasy (e.g., "*After seeing a play or movie, I have felt as though I were one of the characters.*", $\alpha = 0.75$), (3) Perspective taking (e.g., "*I try to look at everybody's side of a disagreement before I make a decision.*", $\alpha = 0.75$), and (4) Personal distress (e.g., "*I sometimes feel helpless when I am in the middle of a very emotional situation.*", $\alpha = 0.75$). One participant had not answered all items of the IRI and was excluded from the respective correlational analysis.

2.5 | Statistical analysis

Analyses were conducted with IBM SPSS (Version 29). First, for each muscle (2: corrugator, zygomaticus) and emotion direction (2: Happy-Distress, Distress-Happy), a 6 (Time) × 2 (Parity) × 2 (Stimulus Age) ANCOVA with Participant Age as a covariate was conducted to examine if the two groups differed in their EMG responses or the timing of the EMG responses. Greenhouse–Geisser correction was used when the sphericity assumption was violated to reduce the risk of Type I error.

Second, for the reaction times, a 2 (Parity) × 2 (Stimulus Age) × 2 (Emotion Direction) ANCOVA (with Participant Age as a covariate) was performed to investigate whether mothers and non-mothers differ in their ability to recognize the emotion change on the stimulus face.

Third, Pearson correlation coefficients were calculated separately for both groups to analyze associations between EMG responses, testosterone levels, and self-reported empathy. For the correlation analyses, the EMG responses were averaged based on muscle region and the corresponding emotion to reduce the number of tests. In other words, to obtain an averaged measure of zygomaticus response to happy expressions, zygomatic activity across the first 3 s during happy-distress videos and the last 3 s during distress-happy videos were calculated. Conversely, for corrugator, activity during the first 3 s of distress-happy trials and the last 3 s of happy-distress trials were calculated. Testosterone levels were square root transformed to meet the normality assumption, inspected visually via Q-Q plots. The results did not differ when replicated with the original values.

3 | RESULTS

3.1 | Main outcome: EMG Responses to emotional facial expressions

3.1.1 | Corrugator responses to happy-distress faces

There was a significant main effect of Time on corrugator responses to expressions changing from happy to distress ($F(1,6.32) = 8.24$, $p < 0.001$, $\eta_p^2 = 0.068$), indicating increasing corrugator activity as a function of time. Time interacted with Parity ($F(1,2.33) = 7.03$, $p < 0.001$, $\eta_p^2 = 0.059$), which indicates that mothers and non-mothers showed differential corrugator reactivity during the six-second video. Post-hoc pairwise comparisons with Bonferroni correction revealed that mothers had more relaxation in their corrugator muscle than non-mothers in the first second of the video ($F(1,113) = 6.63$, $p = 0.011$, $\eta_p^2 = 0.055$), whereas during the fifth second mothers had stronger activation of the corrugator ($F(1,113) = 3.97$, $p = 0.049$, $\eta_p^2 = 0.034$). This interaction is illustrated in Figure 2A, which indicates mothers showing more relaxation in their corrugator muscle during the first seconds of the video (i.e., during the happy expression) and larger corrugator activation from the midpoint of the video onwards (i.e., during the distress expression), with no significant difference between infant and adult stimuli. Parity had no main effect on the corrugator responses, and no other main effects or interactions were found (for more information see Table 1).

3.1.2 | Corrugator responses to distress-happy faces

When the stimulus faces showed the expression changing from distress to happy, we found a main effect of participant age

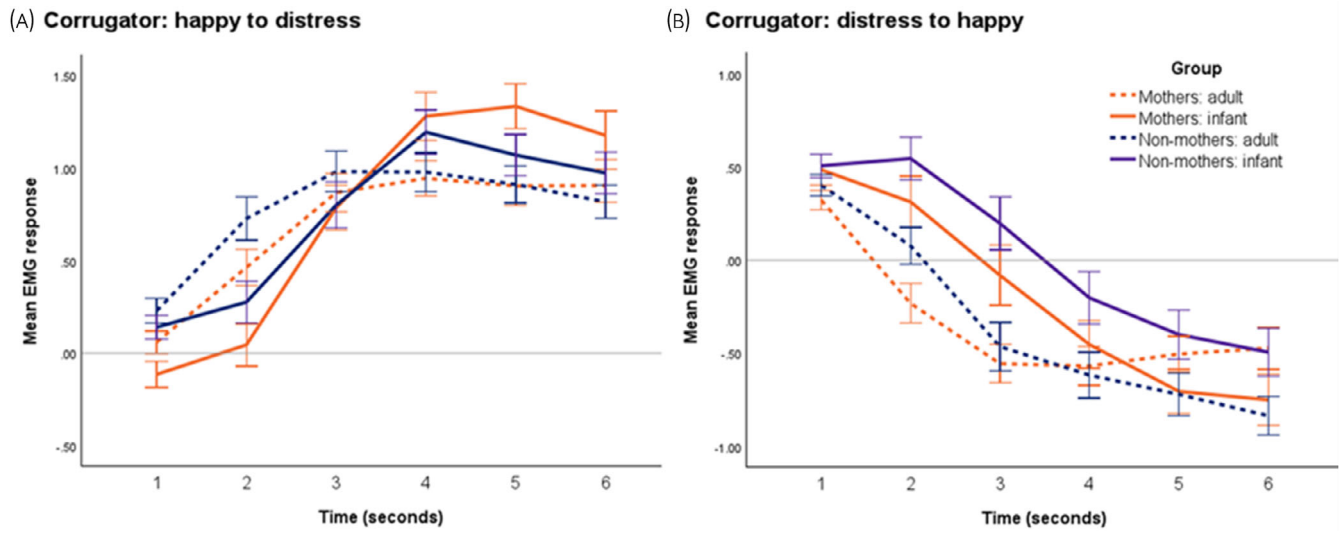

FIGURE 2 Corrugator muscle responses across parity groups and stimulus age. Values at full second marks were averaged from the preceding second's muscle response. Error bars represent standard error of the mean. Non-mothers are depicted with blue lines and mothers with red lines. Infant faces are marked with solid lines and adult faces with dotted lines. (A) Stimulus expression changing from happy to distress. (B) Stimulus expression changing from distress to happy.

TABLE 1 ANCOVA for the corrugator supercilii muscle (Greenhouse–Geisser adjusted).

	F(*df*)	*p*	η_p^2
Happy—Distress			
Parity	0.18 (1)	0.676	0.002
Participant age	2.02 (1)	0.158	0.018
Stimulus (infant/adult)	1.69 (1)	0.197	0.015
Time	8.24 (6.32)	*<0.001*	0.068
Time*stimulus	0.86 (2.14)	0.464	0.008
Parity*stimulus	0.00 (1)	0.964	0.000
Parity*time	7.03 (2.33)	*<0.001*	0.059
Parity*stimulus*time	1.19 (3.16)	0.313	0.010
Distress—Happy			
Parity	0.90 (1)	0.765	0.001
Participant age	4.01 (1)	*0.048*	0.034
Stimulus (infant/adult)	0.26 (1)	0.609	0.002
Time	0.82 (2.57)	0.466	0.007
Time*stimulus	0.61 (2.89)	0.601	0.005
Parity*stimulus	5.16 (1)	*0.025*	0.044
Parity*time	2.01 (2.56)	0.12	0.017
Parity*stimulus*time	5.27 (2.89)	*0.002*	0.045

TABLE 2 ANCOVA for Zygomaticus Major muscle (Greenhouse–Geisser adjusted).

	F(*df*)	*p*	η_p^2
Happy—Distress			
Parity	0.18 (1)	0.671	0.002
Participant age	2.32 (1)	0.131	0.020
Stimulus (infant/adult)	0.20 (1)	0.654	0.002
Time	0.40 (3.02)	0.758	0.003
Time*stimulus	2.29 (1.24)	0.074	0.020
Parity*stimulus	0.99 (1)	0.321	0.009
Parity*time	3.55 (3.02)	*0.014*	0.030
Parity*stimulus*time	1.55 (3.18)	0.198	0.014
Distress—Happy			
Parity	1.73 (1)	0.191	0.015
Participant age	0.03 (1)	0.866	0.000
Stimulus (infant/adult)	1.11 (1)	0.294	0.010
Time	2.85 (2.69)	*0.043*	0.025
Time*stimulus	1.65 (3.28)	0.173	0.014
Parity*stimulus	6.18 (1)	*0.014*	0.052
Parity*time	0.46 (2.69)	0.687	0.004
Parity*stimulus*time	6.19 (3.28)	*<0.001*	0.052

($F(1,1) = 4.01$, $p = 0.048$, $\eta_p^2 = 0.34$), as older age was associated with smaller corrugator responses over all time points ($r = -0.20$, $p = 0.034$). Furthermore, a significant interaction between Parity and Stimulus Age ($F(1,1) = 5.16$, $p = 0.025$, $\eta_p^2 = 0.044$) emerged along with a significant Time*Parity*Stimulus Age interaction ($F(1,2.89) = 5.27$, $p = 0.002$, $\eta_p^2 = 0.045$). Figure 2B illustrates that in response to adult faces, non-mothers' corrugator muscle appeared to relax more than that of the mothers towards the end of the video during which the stimulus face was smiling. To explore the three-way interaction of Time, Parity, and Stimulus age the same analyses were performed but this time for infant and adult conditions separately. These follow-up analyses revealed that with adult faces as stimulus, the Time*Parity interaction was significant ($F(1,2.70) = 5.78$, $p < 0.001$, $\eta_p^2 = 0.049$), as non-mothers had more relaxation than mothers in their corrugator

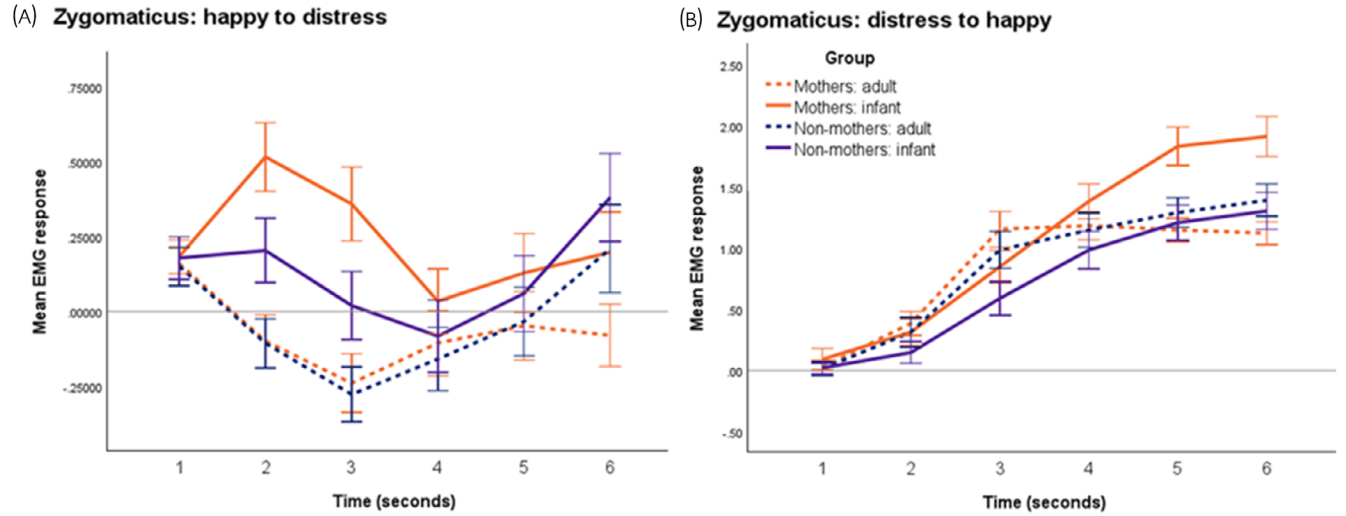

FIGURE 3 Zygomaticus muscle responses across parity groups and stimulus age. Values at full second marks were averaged from the preceding second's muscle response. Error bars represent standard error of the mean. Non-mothers are depicted with blue lines and mothers with red lines. Infant faces are marked with solid lines and adult faces with dotted lines. (A) Stimulus expression changing from happy to distress. (B) Stimulus expression changing from distress to happy.

muscle during the last 2 s where the stimulus was smiling (5th second: $F(1,113) = 5.83$, $p = 0.017$, $\eta_p^2 = 0.049$; 6th second: $F(1,113) = 10.21$, $p = 0.002$, $\eta_p^2 = 0.083$). No main effect of Parity ($F(1,1) = 2.34$, $p = 0.129$, $\eta_p^2 = 0.020$) or Time ($F(1,2.70) = 0.17$, $p = 0.899$, $\eta_p^2 = 0.002$) were found in EMG responses to adult faces. Furthermore, for infant stimuli there was no significant Time*Parity interaction ($F(1,2.72) = 0.19$, $p = 0.888$, $\eta_p^2 = 0.002$), no main effect of Parity ($F(1,1) = 0.43$, $p = 0.511$, $\eta_p^2 = 0.004$), nor a main effect of Time ($F(1,2.72) = 1.34$, $p = 263.$, $\eta_p^2 = 0.012$).

3.1.3 | Zygomaticus responses to happy-distress faces

Considering zygomaticus responses to expressions shifting from happy to distress we found a significant interaction between Time and Parity ($F(1,3.02) = 3.55$, $p = 0.014$, $\eta_p^2 = 0.30$; Table 2). Figure 3A illustrates this interaction. The interaction was further explored with post-hoc Bonferroni-corrected pairwise comparisons revealing that during the last second when the stimulus expressed distress, mothers had a stronger zygomaticus relaxation than non-mothers ($F(1,113) = 4.97$, $p = 0.028$, $\eta_p^2 = 0.042$). No main effects or other interactions were found.

3.1.4 | Zygomaticus responses to distress-happy faces

Time had a main effect on zygomaticus responses ($F(1,2.69) = 2.85$, $p = 0.043$, $\eta_p^2 = 0.025$). Figure 3B shows that zygomaticus activity increased in both groups throughout the videos. Stimulus Age and Parity showed an interaction effect ($F(1,1) = 6.18$, $p = 0.014$, $\eta_p^2 = 0.052$) and there was a three-way interaction between Parity, Time, and Stimulus age ($F(1,3.28) = 6.19$, $p < 0.001$, $\eta_p^2 = 0.052$). Follow-up analyses performed separately for infant and adult faces to break down the three-way interaction showed a main effect of Parity for infant faces ($F(1,1) = 5.54$, $p = 0.020$, $\eta_p^2 = 0.047$) but not for adult faces ($F(1,1) = 0.33$, $p = 0.566$, $\eta_p^2 = 0.003$). Similarly, the Time*Parity interaction was significant with infant faces ($F(1,2.98) = 3.74$, $p = 0.012$, $\eta_p^2 = 0.032$) but not with adult faces as stimuli ($F(1,2.99) = 1.25$, $p = 0.290$, $\eta_p^2 = 0.011$). Post-hoc pairwise comparisons with Bonferroni correction for infant faces showed that mothers had stronger zygomaticus activation than non-mothers during the last 2 s of the videos when the infants were smiling (5th second: $F(1,113) = 7.50$, $p = 0.007$, $\eta_p^2 = 0.062$; 6th second: $F(1,113) = 9.49$, $p = 0.003$, $\eta_p^2 = 0.077$). Similarly, Figure 3B illustrates that with infant faces the mothers' zygomaticus response was larger than non-mothers' or both groups' responses to the adult stimulus.

3.2 | Reaction times in perceiving emotion offset

Mothers and non-mothers did not differ in any of the reaction times across the two emotions and stimulus ages (Table 3). Two 2-way ANCOVAs performed for both emotion change directions (happy to distress and distress to happy) showed that there were no significant main effects of Parity or interactions between Parity and Stimulus Age (Table 4). However, Stimulus Age had a main effect on both conditions: when watching infant faces, both groups needed more time to recognize the emotion offset (Distress to Happy: $F(1,1) = 6.54$, $p = 0.012$, $\eta_p^2 = 0.055$; Happy to Distress: $F(1,1) = 4.96$, $p = 0.028$, $\eta_p^2 = 0.042$) as can be observed from Table 4 and Figure 4.

TABLE 3 Descriptive statistics of self-reported empathy (IRI), reaction times, and testosterone levels.

	Mothers ($n = 54$)			Non-mothers ($n = 62$)				
	Mean (*sd*)	min	max	Mean (*sd*)	min	max	*t* (*df*)	*p*
IRI								
Perspective taking	3.6 (0.7)	2.43	5.0	3.7 (0.6)	2.0	4.86	0.94 (113)	0.349
Fantasy	3.7 (0.7)	1.86	5.0	4.0 (0.6)	2.29	5.0	2.36 (95.99)	0.02
Empathic concern	3.9 (0.4)	3.0	4.43	3.8 (0.5)	1.86	4.57	−1.25 (113)	0.215
Personal distress	2.8 (0.6)	1.86	4.0	2.9 (0.5)	1.71	4.0	0.92 (113)	0.362
Reaction times (ms)								
Adult stimulus								
Distress—Happy	2848.6 (684.2)	1438.44	4717.50	2806.1 (599.2)	1456.44	4164.81	−0.36 (115)	0.720
Happy—Distress	2460.1 (660.0)	1313.38	3880.19	2390.7 (599.1)	1113.19	3553.69	−0.60 (115)	0.548
Infant stimulus								
Distress—Happy	3191.8 (606.6)	1955.80	4323.70	3325.0 (546.7)	1348.70	4209.90	1.25 (115)	0.214
Happy—Distress	3140.4 (569.6)	1961.94	4498.94	3224.7 (556.4)	1866.06	4397.38	0.81 (115)	0.420
T1 Testosterone (pg/ml)	23.7 (11.9)	6.61	67.19	26.0 (15.7)	1.01	76.90	0.47 (111)	0.641
T2 Testosterone (pg/ml)	22.9 (13.5)	4.45	72.4	24.2 (13.9)	3.52	62.37	0.40 (111)	0.694

Note: Testosterone values in the table are the original values, but the *t*-test was performed for square root transformed values. Significance is presented with two-sided *p*-values.

TABLE 4 ANCOVA table for reaction times in the emotion offset recognition task.

	F(*df*)	*p*	η_p^2
Happy—Distress			
Parity	0.34 (1)	0.561	0.003
Participant age	0.98 (1)	0.325	0.009
Stimulus age	4.96 (1)	*0.028*	0.042
Parity*Stimulus age	3.85 (1)	0.052	0.033
Stimulus age*Participant age	0.02 (1)	0.890	0.000
Distress—Happy			
Parity	0.03 (1)	0.954	0.000
Participant age	0.42 (1)	0.519	0.004
Stimulus age	6.54 (1)	*0.012*	0.055
Parity*Stimulus age	2.77 (1)	0.099	0.024
Stimulus age*Participant age	1.37 (1)	0.244	0.012

3.3 | Correlations between variables

In the non-mothers' group, using Bonferroni-adjusted alpha levels of 0.0125 (four different EMG responses), testosterone levels from both samples were inversely associated with the zygomatic response to infant happy expressions (T1: $r = -0.42$, $p < 0.001$; T2: $r = -0.36$, $p = 0.005$), with higher testosterone levels related to smaller zygomatic responses to smiling infants. No significant correlations were found in mothers. Testosterone had no associations with EMG responses or any of the self-reported empathy scales in either group (Table 5).

Correlations between EMG responses and self-reported empathy were not found using Bonferroni-adjusted alpha levels of 0.0125 (four IRI scales). Non-mothers scored higher than mothers on the Fantasy scale ($t[95.99] = 2.36$, two-sided $p = 0.02$, see Table 3), whereas the two groups did not differ on the other empathy questionnaire scales.

4 | DISCUSSION

Mirroring other people's emotions is a key feature of human interaction.[2] Parental mirroring of infant emotions helps the parent to attune to infant needs,[6] which, in turn, is a prerequisite for sensitive caregiving.[1] One aspect of mirroring is the automatic facial muscle responses to emotional expressions of other people.[7,8] Our goal was to investigate whether first-time mothers of infants aged 7 months and non-mothers differ in their facial muscle reactivity towards infant emotions and whether such reactivity is associated with salivary testosterone level, emotion offset recognition, or self-reported empathy. During the experiment, the participants watched 6-s trials of adult and infant facial expressions changing from distress to happy or vice versa, and they were instructed to mark the offset of the original emotion expression on each trial. During the task, we measured facial muscle reactivity from two muscle regions: corrugator supercilii (associated with frowning) and zygomaticus major (associated with smiling).

Both groups showed a robust zygomaticus response to happy expressions. However, in the distress—happy trials, mothers showed heightened zygomaticus activation to infant faces during the final part of the trial when the expression had shifted to a full smile (Figure 3B; see also the Parity × Stimulus Age effects in Table 2), whereas mothers and non-mothers showed similar zygomaticus responses to

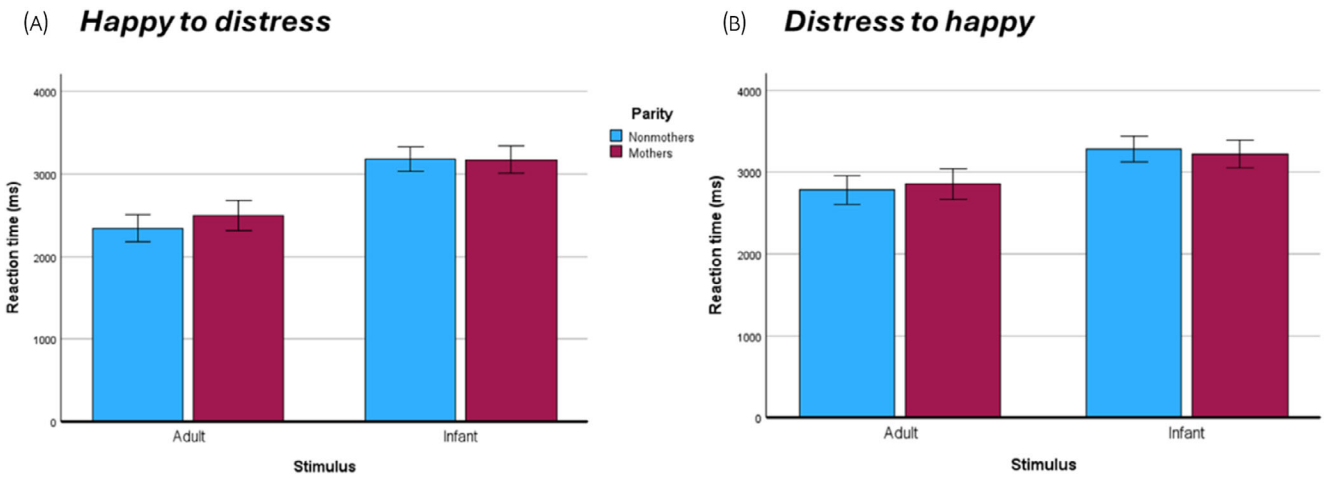

FIGURE 4 Reaction times with stimulus expression changing from happy to distress (A) and vice versa (B). Non-mothers depicted with blue bars and mothers with red bars.

TABLE 5 Pearson correlations between mean corrugator and zygomaticus responses to distressed and happy faces (respectively), salivary testosterone levels, Interpersonal Reactivity Index, and emotion offset recognition reaction times.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Zygomaticus response for happy adult faces	–	0.33	−0.20	0.06	−0.11	−0.10	−0.13	0.09	0.02	0.20
2. Zygomaticus response for happy infant faces	0.47***	–	−0.22	0.08	−0.01	−0.17	−0.01	0.17	−0.05	0.07
3. Corrugator response for distressed adult faces	−0.30*	−0.34**	–	0.69***	0.02	−0.07	0.22	−0.04	0.12	−0.27
4. Corrugator response for distressed infant faces	−0.17	−0.26	0.71***	–	−0.07	−0.13	0.31	0.02	0.05	0.01
5. Testosterone T1 (pg/ml)	−0.08	−0.42***	−0.02	−0.11	–	0.80***	−0.05	−0.06	−0.13	−0.07
6. Testosterone T2 (pg/ml)	−0.02	−0.36**	−0.05	−0.16	0.85***	–	−0.11	−0.24	−0.13	−0.21
7. IRI Fantasy	−0.00	0.02	0.03	0.11	−0.14	−0.12	–	0.18	−0.16	−0.13
8. IRI Empathic concern	−0.08	−0.22	0.01	−0.17	0.08	0.15	0.17	–	0.28	0.38**
9. IRI Perspective taking	0.06	−0.07	0.08	0.04	0.08	0.14	0.18	0.46***	–	−0.01
10. IRI Personal distress	−0.09	−0.13	0.01	−0.02	0.10	0.09	0.01	−0.04	0.00	–

Note: Data for non-mothers is shown below the diagonal and for mothers above the diagonal. *adjusted $p < 0.0125$; **$p < 0.01$; ***$p < 0.001$.

smiling adult faces (Figure 3B). We interpret these findings to indicate heightened affective empathy to positive infant emotion signals in new mothers. Similarly, in Bjertrup et al.,[17] mothers compared to non-mothers displayed a more positive facial expression while watching a video of child laughter. The current finding is also in line with our previous study with the same participants showing first-time mothers being more likely than non-mothers to prolong their viewing of smiling infant faces when salivary hormonal levels of testosterone, estradiol, and cortisol were controlled,[27] and with studies investigating task interference by emotional faces, which have found infant and child stimuli to capture attention more strongly in mothers than in non-mothers.[18–20] Mothers' dopamine-associated reward-processing regions have been shown to activate especially when viewing their own infants,[34] but given our results, it is likely that first-time mothers are generally more susceptible to smiling infant faces compared to women without children. Responding to each other's smiles is a key element of parent–infant interaction, creating synchrony between the dyad and thus advancing child emotional development.[38,39]

Regarding corrugator responses, we found a significant interaction between time and parity when the participants were viewing expressions changing from happy to distress (see Table 1 and Figure 2A): mothers had a more pronounced difference in the corrugator activity between the beginning of the video and the end of the video regardless of stimulus age, indicating more relaxation during the smiling stimuli and more activation during distressed stimuli. In earlier studies, infant distress has been found to evoke more extreme ratings,[40] and stronger autonomic nervous system reactions (galvanic skin responses) in mothers than non-mothers.[17] Additionally, mothers have been found to show bilaterally heightened brain activity in their insulae in response to watching others in pain.[41] In the present study,

however, because the group difference emerged primarily as a time-by-parity interaction (i.e., a stronger differential change from happy to distress, Figure 2B), the corrugator pattern cannot be straightforwardly attributed to heightened sensitivity specifically to distress cues. It may reflect increased responding to the emerging negative expression, stronger relaxation after the initial positive expression, or a combination of both.[42]

When the stimulus expression was changing from distressed to smiling (Figure 2B), there were no differences between mothers and non-mothers in their frowning (i.e., corrugator) responses. Also, in response to adult stimuli, non-mothers had more corrugator relaxation as the video progressed towards a smile (Figure 2B). This raises the question of why did mothers have a differential corrugator response only in response to expressions changing from happy to distress, but not vice versa? One plausible explanation is that the emotion in the beginning of the video "sets the tone" or context for the situation, thus leading to differential reactivity between the stimulus emotion directions. Earlier studies have shown maternal sensitivity to infant distress and non-distress to be somewhat separate dimensions of sensitive parenting.[3,43] Thus, in our study, the videos starting with distress might evoke a different action tendency than the ones starting with a positive affect: the video suddenly starting with distressed expression might be more alerting to both groups and require immediate attention whereas in the happy-distress condition mothers might be more susceptible to the slowly emerging distress. This might also explain the results of happy to distress trials, where we found no differences between mothers and non-mothers in their zygomaticus responses in the first half of the video (smiling), but mothers had more zygomaticus relaxation during the last second (Figure 3A and Table 2). Emerging distressed infant expressions may represent a special situation for mothers: rather than eliciting straightforward imitation of the distressed facial configuration, such cues may primarily trigger caregiving-related action tendencies (e.g., soothing and comforting) and empathic concern.[44] This could contribute to more complex facial mimicry patterns in mothers when confronted with distressed infants. More broadly, mimicry effects may be less pronounced for negative than for positive facial expressions. For example, in one study, mimicry was reported to be diminished for sad expressions and absent for angry expressions, independent of the expressor's age.[45]

Both groups needed more time to recognize the emotion offset from infant faces compared to adult faces (Figure 4 and Table 4). This can be due to a few reasons. First, infant emotions might not be as distinctive as the corresponding adult emotions, leading to a more uncertain interpretation of the emotion offset.[33] Second, it is possible that infant faces are a particularly attention-grabbing stimulus for humans, as indicated by earlier studies showing that infant faces capture attention more strongly than adult faces.[18,19,46] The attention bias to infant faces may thus have caused slower reaction times while viewing emotional infant faces compared to adult faces. However, in earlier studies, task interference by infant faces has been more pronounced in mothers than non-mothers,[18–20] whereas in our study the two groups did not differ in their reaction times during the emotion offset recognition task. This could relate to stimulus differences, as in our study the video stimuli did not have a clear middle point with a truly neutral expression, which might have affected the interpretation of the stimulus emotion changes. Adding a neutral expression between the two extremes might provide a clearer understanding of the recognition of emotion offset.

Testosterone levels from two saliva samples were negatively associated with zygomatic responses to infant smiles in non-mothers (Table 5). This is in line with previous studies associating higher testosterone levels with lower parental sensitivity both in women[32] and in men.[47–49] In addition, diurnal testosterone variability may also matter, as fathers with greater day–night fluctuation in testosterone showed higher sensitivity, whereas mothers showed the opposite pattern of greater diurnal variability linked with lower sensitivity.[50] Furthermore, in our previous study linking hormonal levels to motivation to view emotional infant faces, we found a strong negative connection between testosterone level and the willingness to view emotional infant faces.[27] Taken together, these studies suggest that lower or more flexibly regulated testosterone levels are generally conducive to warm, engagement-oriented reactions to infant signals, particularly in men, whereas in women the relation may be more complex. In our sample, the absence of a significant correlation between testosterone and facial mimicry in mothers could be related to hormonal changes associated with the transition to parenthood. Both pregnancy and breastfeeding influence testosterone levels, which increase during pregnancy, decrease after birth and remain lower in lactating women and parents in general compared to non-parents.[51–54] It must be noted, however, that in our sample mothers and non-mothers did not significantly differ in their salivary testosterone levels and we did not take into consideration other hormones that might be related to facial muscle responses either on their own or in interaction with other hormones. Nevertheless, we consider the current findings linking higher testosterone levels to smaller zygomaticus responses in non-mothers robust and reliable, as they were replicated across two measurement points.

EMG activity was not related to self-reported empathy traits in either mothers or non-mothers. This is somewhat different from some of the earlier studies linking facial muscle responses and self-reported empathy traits.[10–12] Further research regarding self-reported empathy and facial muscle responses is needed as the previous studies have included different self-report measures and demographics. In addition, the potential association between facial mimicry and empathic traits is related to a debate over whether facial muscle responses to others' emotion signals reflect emotional contagion and affective responding and, thus, are components of empathy,[10] or whether they can be considered as more automatic motor reactions evolved to support communicative and interactive functions without accompanying affective arousal.[55,56] Our results could be seen to support the latter model given the mostly non-significant associations between facial mimicry and self-reported empathy traits. Another possible explanation is that mothers and non-mothers do differ in their emotional empathy and emotional contagion, but this might not be reflected in the self-report measures. Similarly, the IRI has been found to be unrelated to EEG-based measures of empathy for pain,[57] pointing to limitations of

self-report empathy measures[58] in explaining variation in more automatic physiological responses.

In this study, we compared mothers and non-mothers in facial mimicry to infant and adult facial expressions and found that mothers had a heightened smiling response towards happy infant (but not adult) faces and a heightened frowning response to faces expressing distress, regardless of stimulus age. This might reflect heightened affective empathy in new mothers. In the future, it is important to investigate the impact of parity on social perception, especially when using infant stimuli. Previous studies have consistently demonstrated that the transition to parenthood influences brain structure and hormonal levels.[59,60] Furthermore, the current study and other findings (e.g.,[61,62]) suggest that there are changes in psychophysiological responses to infant emotions especially in first-time parents as compared to more experienced parents. For example, when comparing nulliparous, primiparous, and multiparous women's parasympathetic responses to infant cry stimuli, different patterns of autonomic responding to infant distress emerged in first-time mothers compared to mothers with two or more children.[63] The cross-sectional and correlational nature of our study does not permit causal inference, and thus any robust conclusions about the transition to parenthood need to be made carefully. However, this study underlines the importance of studying the sensitive life period of becoming a parent, for it might have significant impact on empathy and emotional reactivity to children's emotion signals.

AUTHOR CONTRIBUTIONS

Mikko J. Peltola: Conceptualization; investigation; funding acquisition; writing – original draft; methodology; writing – review and editing; project administration; data curation; supervision; resources; software; formal analysis; validation; visualization. **Marian J. Bakermans-Kranenburg:** Methodology; writing – review and editing; supervision; conceptualization; formal analysis. **Hanneli Sinisalo:** Writing – original draft; methodology; visualization; writing – review and editing; formal analysis; data curation; conceptualization; investigation; software; validation; project administration. **Sonja Veistola:** Conceptualization; investigation; writing – review and editing; methodology; formal analysis.

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CONFLICT OF INTEREST STATEMENT

We have no conflicts of interest to disclose.

PEER REVIEW

For transparency, the peer review documents associated with this article are available at https://doi.org/10.1111/jne.70206.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in OSF at https://osf.io/92v3w/, reference number 92v3w.

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