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Original article

Maternal electrophysiological response to interactions with their own child: A preliminary study in a sample of same-sex mothers

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ABSTRACT

Past research has examined the link between maternal electrophysiological responses, self-reported measures, and the quality of caregiving. However, these patterns have remained unexplored in same-sex mothers. Furthermore, no study has yet investigated how maternal involvement in childcare is associated with event-related potential (ERP) responses to child stimuli. To address these gaps, a sample of 32 same-sex mothers participated in the study and were videotaped during a 15-minute structured play session with their child (aged 3–11 years). The interactions were coded using the Emotional Availability Scales, and the experimental stimuli for the EEG task were derived from these recordings. Mothers then participated in an EEG task, evaluating videotapes of their own and other mother-child interactions, which displayed successful or unsuccessful exchanges. Maternal involvement in childcare was assessed using an Italian-translated version of the Child Caregiving Involvement Scale. Same-sex mothers exhibited a stronger response to interactions with their own child. Mothers with higher caregiving involvement demonstrated increased LPP activation in response to unsuccessful interactions with their own child, though this result did not remain statistically significant after post-hoc corrections. Mothers who displayed greater sensitivity, non-intrusiveness, and non-hostility showed an amplified LPP response to unsuccessful interactions with their child. This study preliminarily highlights the neural mechanisms underlying sensitive and responsive caregiving in same-sex mothers. Further inclusive research is needed to broaden the understanding of parenting determinants and outcomes, as the diversity of modern families deserves more accurate representation in both social policy and research.

Introduction

According to an ethological and evolutionary framework, the mother-child bond plays a unique role in promoting the child's survival, security, and healthy development (Bowlby, 1969/1982). Across different species and cultures, mothers engage in a variety of intuitive parenting behaviors in response to child signals, fostering dyadic exchanges and supporting the infant's communicative development (Parsons et al., 2017). Therefore, it is crucial for mothers to promptly and accurately understand their child's signals to provide adequate, consistent, and responsive nurturance and care (Ainsworth & Bell, 1970; Ainsworth et al., 1978). Over the past two decades, research on maternal sensitivity has expanded investigating not only behavioral and representational dimensions but also the neural mechanisms underlying sensitive caregiving (Swain et al., 2011). Previous research has shown that specific neural responses support adaptive caregiving behaviors in parents by eliciting an affective orientation toward a child's stimuli (Young et al., 2017). Using the Event-Related Potentials (ERPs) technique, researchers have investigated the temporal dynamics of maternal brain responses to child cues with millisecond precision (Vuoriainen et al., 2022). Specifically, the Late Positive Potentials (LPP), a sustained positive activity occurring with a latency longer than 300 milliseconds (ms), reflects prolonged attention to motivationally significant stimuli (Olofsson et al., 2008). This component has been shown to be highly sensitive to the biological and motivational relevance of the stimuli (Hajcak et al., 2016). Previous studies have consistently shown that maternal LPP amplitude is significantly larger in response to their own child compared to other children's faces (Grasso et al., 2009; Bernard et al., 2018; Vuoriainen et al., 2022). This evidence confirms that a mother's own child is a salient stimulus that captures and sustains their

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attention (Bernard et al., 2018). However, to the best of our knowledge, prior research on this topic has been limited to samples of mothers from different-sex families, with no evidence yet available regarding same-sex mothers. Although the number of same-sex parent families is increasing globally, with children in these families showing comparable developmental outcomes to those in different-sex parent families (Golombok, 2020), research on the neural correlates of parenting in same-sex families remains limited. Studying same-sex mothers' neural responses is essential for understanding caregiving across diverse family structures (Giannotti et al., 2022). For instance, only a limited number of studies have explored temporal dynamics using ERP methodology in the context of different family structures, including foster or adoptive parents (see Maupin et al., 2015 for a review). A study conducted by Grasso et al. (2009) investigated ERP responses in 14 biological mothers and 14 foster/adoptive mothers who viewed facial pictures of their own child, familiar and unfamiliar children, and unfamiliar adults during a computerized task during an EEG session. All mothers showed a larger LPP amplitude to images of their own child compared to all other stimuli, regardless of the biological tie with their child. Another longitudinal study (Bick et al., 2013) consistently found that foster mothers exhibited a significantly larger P300 response to their own foster child compared to unfamiliar children. Moreover, a significant association was found between maternal oxytocin levels and both electrophysiological (ERP) brain activity and quality of caregiving in response to their foster child. Therefore, initial evidence has preliminarily suggested that a heightened processing of child cues is not solely tied to biological processes but is also influenced by parenting experiences (Maupin et al., 2015). Recent findings by Gemignani et al. (2024a) highlighted that direct involvement in childcare is associated with attentional bias toward infant faces in a sample of same-sex mothers. Previous electroencephalography studies examining the effect of maternal parity (Maupin et al., 2019) and duration of motherhood in terms of child age (Kuzava et al., 2020) suggest that these factors may affect the LPP amplitude in response to infant cues, highlighting the role of maternal experience in shaping the neural processing of child affective cues. However, despite the potential relevance of this association, there is a lack of research investigating how maternal involvement in routine childcare activities is related to ERP responses and quality of caregiving behaviors.

The importance of studying adult responses to infant cues lies in the fact that individual differences in processing these cues can serve as early markers of caregiving quality. In relation to this, an increasing body of evidence suggests that differences in maternal qualities are associated with different ERP responses to child cues. Notably, a larger LPP amplitude in response to infant faces has been associated with more favorable indicators of parenting quality (for a meta-analysis, see Vuoriainen et al., 2022), whereas a decreased LPP amplitude to infant cues has been associated with less optimal maternal caregiving behaviors (Kuzava et al., 2019). In particular, Rodrigo and colleagues (2011) showed that neglectful mothers exhibited a reduced LPP response to infant emotional expressions compared to non-neglectful mothers without history of maltreatment, substance abuse, mental health issues, or low IQ. Bernard and colleagues (2015) found that a greater LPP amplitude to own versus other children was associated with higher levels of maternal sensitivity, in a sample of Child Protective Services (CPS)–referred mothers. Finally, Kuzava and colleagues (2019) found that maternal profiles characterized by undifferentiated LPP responses to emotional expressions of infants were associated with lower levels of maternal sensitivity. Given the crucial role of neural processing in understanding the mechanisms underlying sensitive parenting, it is necessary to extend research to validate these findings among more diverse populations (Maupin et al., 2015). For instance, valuable insights could be gained by including samples of mothers from varied family contexts, such as same-sex families, to broaden our knowledge on determinants of parental sensitivity across different caregiving environments. Although we did not expect any differences based on the type of family structure (Gemignani et al., 2024b), our focus on same-sex mothers is primarily motivated by the fact that this population has been understudied. In this regard, inclusive research on different family structures is essential, both conceptually and methodologically, as it allows researchers to explore various parental roles and arrangements beyond traditional models, while disentangling the influence of sex and caregiving roles (Giannotti et al., 2022). For instance, previous research has consistently showed that same-sex families tend to share division of labor and responsibilities in childcare more equally (Patterson et al., 2013). Thus, investigating the specific mechanisms that support sensitive and responsive parenting in diverse family configurations is essential for expanding our understanding and models of human caregiving. In light of the dearth of prior research on same-sex mothers' families, the present study adopted an exploratory approach to investigate this topic. Overall, current perspectives on parenting suggest that multiple indicators of maternal responses, such as electrophysiological measures, self-reports, and direct observation of behaviors, may provide more comprehensive and informative findings (Teti & Cole, 2011; Groh et al., 2015). Therefore, we adopted a multi-method research protocol to investigate maternal responses to interactions with their own child in a sample of same-sex mothers. We first examined the LPP response to own versus other parent-child interactions using dynamic videoclips as visual stimuli. Then, we explored the relationships between the LPP amplitude and i) the degree of maternal involvement in childcare, and ii) the quality of maternal behaviors during the interaction with the child. Based on prior findings, we expected that stimuli of one's own parent-child interactions would elicit a larger LPP amplitude compared to unfamiliar parent-child interactions. In addition, in line with previous evidence, we expected that i) greater involvement in childcare and ii) more sensitive and responsive maternal behaviors would be associated with a larger LPP amplitude in response to interactions with their own child.

Methods

Participants

A group of 32 mothers and their children (14 females and 18 males) being in a same-sex couple participated in the study. The recruitment of most of the mothers was made through the Italian Association *Famiglie Arcobaleno* (i.e., an association that unites same-sex parents in Italy), which sent an invitation to all the members through a mailing list. A snowball sampling was also used, whereby mothers who participated in the study were asked to forward the study invitation to other same-sex mother families. To be included in the sample, mothers should 1) have raised their child since birth; 2) speak Italian fluently; 3) not be pregnant at the time of the experiment. The age of the mothers' children ranged from 3 to 11 years (Table 1). Both members of each couple of same-sex mothers were invited to participate in the study. However, while 30 mothers (94 %) participated in the experiment with their partners ($N = 15$ couples), 2 mothers (6 %) participated alone, as their partner was not available or willing to participate. All participants reported normal vision, or a vision corrected to normal. The majority of participants were Italian (94 %), but two of them (6 %) reported having a dual nationality. Mothers were compensated for their participation. For couples where both mothers participated, each mother completed all three phases of the study individually. During Phase I, each mother interacted separately with their child, creating unique dyadic interactions. For Phase II, EEG recordings were conducted individually for each mother, using personalized stimuli derived from their own interactions with their child. This approach maximized our sample size given the recruitment challenges associated with this specific population. We acknowledge that this introduces potential non-independence in our data that should be addressed in future studies with larger samples through appropriate multilevel modeling approaches.

Table 1
Characteristics of participants; *N*=number; *M*=mean; *P*=percentage; SD=standard deviations.

Variable	N	M(SD) or P
Parent age	32	43.4 (6.4)
Child age	32	4.9 (2.2)
Number child	32	
Primiparous	22	69 %
Multiparous	10	31 %
Educational level	32	
Middle-school diploma	1	3 %
High-school diploma	11	34 %
Bachelor's degree	4	13 %
Master's degree	8	25 %
Postgraduate level	8	25 %
Nationality	32	
Italian	30	94 %
Non-Italian	2	6 %
Relationship with partner	32	
6–10 years	8	25 %
11–15 years	13	41 %
>15 years	11	34 %
Involvement (me)	32	33.4 (6.5)
EA Sensitivity	31	5.7 (0.8)
EA Structuring	31	5.7 (1.0)
EA Non Intrusiveness	31	6.5 (0.8)
EA Non Hostility	31	6.8 (0.5)
EA (child) Responsiveness	31	5.6 (0.8)
EA (child) Involvement	31	5.5 (1.0)

Note. EA: Emotional Availability.

Procedure

The current study was divided into three phases. Phase I concerned mothers engaging in a playful interaction with their child recorded during a Zoom meeting. Each interaction was videotaped to create the experimental stimuli for the mothers' EEG recording, and later coded using the Emotional Availability Scales (EAS; Biringen & Easterbrooks, 2012). Videos of each member of a couple were acquired on the same day. Mother-child interactions were coded by two independent raters trained and reliable in the system. Disagreements between the raters were discussed until consensus was achieved. Phase II involved the mothers' laboratory visit. Mothers were invited to take part in the EEG procedure only if they did not report any neurological problems and their health conditions were suitable for the EEG recording; thus, they answered pre-screening questions to determine their eligibility for the study. EEG recordings were conducted on the same day for each member of the couple, within a two-month period after the first meeting, based on the parents' availability. Phase III involved the mothers' completion of online self-reports through Qualtrics (Qualtrics, Provo, UT). Standard procedures for acquiring informed consent were used, and tasks were briefly described to the mothers prior to the start of each phase. The study was approved by the Ethics Committee of the University of Trento and adhered to the principles of the Declaration of Helsinki and its subsequent revisions.

Phase I: mother-child interactions

In Phase I, mothers received a puzzle appropriate for their child's age and were invited to a video-recorded Zoom meeting. During the session, mothers were asked to spend around 10 min helping their child do the puzzle. Then, the mothers were told to stop – using a standardized signal - playing and ignore their child for about 1 min. Finally, the mother was told to start playing again with their child. Mothers were instructed to position the camera to ensure that both themselves and their child were visible throughout the play session.

Creation of experimental stimuli

Three-seconds videoclips of mothers' interacting with their own child were extracted from the recordings of the play sessions (Phase I). The video-clips showed both successful (i.e., the parent interacted cooperatively) and unsuccessful (i.e., the parent did not interact with their child) interactions. The final stimuli were selected after being evaluated by four raters for the type of interaction displayed (successful vs. unsuccessful). Raters were asked whether the displayed interaction was clearly successful or unsuccessful, and they could respond by choosing one of the following options: "*yes*" or "*no*", or "*I don't know*". Video-clips were excluded from the final stimuli whether two or more raters responded with "*I don't know*" or "*no*". Selected control stimuli consisted of 20 video-clips (10 successful and 10 unsuccessful) showing unfamiliar parents interacting with their own child. The control stimuli reflected different characteristics in terms of child age and sex, potentially matching a wide range of conditions. Specifically, control stimuli consisted of: 10 successful dyadic interactions, including 6 interactions with children aged 5–7 years and 4 interactions with children aged 8–11 years; 10 unsuccessful dyadic interactions, including 4 interactions with children aged 5–7 years and 6 interactions with children aged 8–11 years. Child-caregiver dyads were balanced by the gender of both the child and the parent across the two age groups considered. The details of the control stimuli are reported in the Supplementary Information (Table S1). All video-clips were cut, converted to gray scale, matched for size and luminance, and audio removed using Videopad Editor Video v16.28 (https://www.nchsoftware.com/videopad/index.html). The stimuli were presented against a uniform gray background.

Emotional Availability (EA) coding

The Emotional Availability Scales 4th edition (EAS; Emde & Easterbrooks, 1985; Biringen & Easterbrooks, 2012) was used to assess the quality of dyadic emotional exchanges between the child and the parent. The EAS include four scales for the parent and two for the child: (1) adult *sensitivity* refers to clear and accurate perception of emotions, responsiveness to emotions, the ability to handle conflictual situations and the awareness of timing; (2) adult *structuring* refers to the ability to facilitate and organize the child's activities by providing appropriate prompts and suggestions during the interaction, without limiting the child's autonomy; (3) adult *non-intrusiveness* refers to the absence of interference, over-direction, over-stimulation, or over-protection; (4) adult *non-hostility* refers to the ability of the adult to interact with the child without showing any signs of hostility, either overt or covert; (5) child *responsiveness* refers to the child's eagerness to respond to the adult interactive attempts, and the child's manifestation of clear signs of pleasure during the interaction; (6) child *involvement* refers to the child's ability to actively engage and involve the adult in the interaction through different modalities. Each scale is associated with a global score, ranging from 1 to 7, with scores above 5.5, in the mid-range around 4 and below 3, indicating optimal, inconsistent and low emotional connection respectively. The instrument has shown good psychometric properties in both normative and clinical populations (Biringen et al., 2014). The inter-rater reliability was calculated using the Intraclass Correlation Coefficient (ICC) on a set of 6 videos for each EA dimension (sensitivity ICC = 0.74; [95 % CI: 0.042 < ICC < 0.957]; structuring ICC = 0.69 [95 % CI: −0.052 < ICC < 0.948]; non-intrusiveness ICC = 0.69 [95 % CI: −0.048 < ICC < 0.949]; non-hostility ICC = 0.77 [95 % CI: 0.114 < ICC < 0.963]; responsiveness ICC = 0.79 [95 % CI: 0.177 < ICC < 0.967]; involvement ICC = 0.84 [95 % CI: 0.304 < ICC < 0.975]).

Phase II: EEG acquisition and pre-processing

In the EEG laboratory, mothers were seated in a dimly lit room and were presented with a passive viewing task during an EEG recording. Upon entering the laboratory, the procedure was briefly explained, after which an electrode cap was positioned on the mother's head. Electrode sites were prepared using conductive paste to minimize impedance. Continuous EEG activity was recorded using an eego sports system (ANTNeuro) at a sampling rate frequency of 1000 Hz, from 64 Ag/AgCl

shielded electrodes referenced online to CPz and placed according to the standard 10–10 locations on an elastic cap (Brain Products). Additionally, an electrooculogram (EOG) electrode was placed under the left eye. Impedance levels were kept below 20 kΩ.

The passive viewing task was developed using Psychopy Software (Peirce et al., 2019). An example of a trial structure is displayed in Fig. 1. The session began with two practice blocks, each consisting of 8 trials. During these practice blocks, each of the four experimental conditions (i.e., successful own interaction, unsuccessful own interaction, successful other interaction, unsuccessful other interaction) was randomly presented four times. In the test phase, each trial started with the presentation of a fixation cross at the center of the screen, which appeared for a jittered duration ranging from 1 to 3 s (s), then a stimulus display was passively presented for 3 s. To ensure full attention to the task, after 6 trials, mothers were asked to evaluate whether the last interaction presented was successful or unsuccessful. Mothers could provide their responses on a dichotomous scale (yes/no). The test phase consisted of 6 test blocks of 40 trials each (i.e., 240 trials in total; 60 trials in each condition, with all trials presented randomly). A self-paced break was offered after each block. During the EEG recordings, mothers were asked to minimize eye, body and mouth/lip movements. The entire task lasted approximately 20 min.

EEG data preprocessing was performed using 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, excluding mastoids and EOG channels. A Butterworth filter with cutoffs of 0.1 Hz and 30 Hz was applied for band-pass filtering. Epochs were segmented for each trial, starting from −400 ms to 3000 ms from the stimulus onset (i.e., long epochs were extracted considering the experiment timing). Baseline correction was performed using the −400 ms to stimulus onset. Artifacts were initially identified and rejected through visual inspection to remove drift and poor channel signals. On average, 2 % of the epochs were discarded. Independent Component Analysis (ICA) using the RUNICA algorithm (Porcaro et al., 2013) was performed. ICA components were visually inspected and selected for removal based on their topography. On average, 0.5 % of the total components were removed due to eye-blink artifacts and an additional 0.5 % due to noise-related components. The IClabel tool (Pion-Tonachini et al., 2019) was used to aid in identifying noise sources. The signal was epoched based on different bins corresponding to different experimental conditions. A more automated artifact rejection was additionally performed, as suggested by the software developers (https://eeglab.org/), with trials exhibiting peak-to-peak amplitudes exceeding ± 70 μV being excluded for removing muscular movements. The percentage of remaining trials for each participant was reported in Table S3. Event-related potentials (ERPs) were computed only if at least 70 % of the original epochs remained after artifact rejection. ERPs were averaged for each condition within a discrete time window and electrode groupings. The LPP component was defined as the mean activity within a 300 to 700 ms time window (e.g., see Endendijk et al., 2018) averaged over the centro-parietal electrodes (Cz, CP1, CP2, Pz; e.g., see Kuzava et al., 2019).

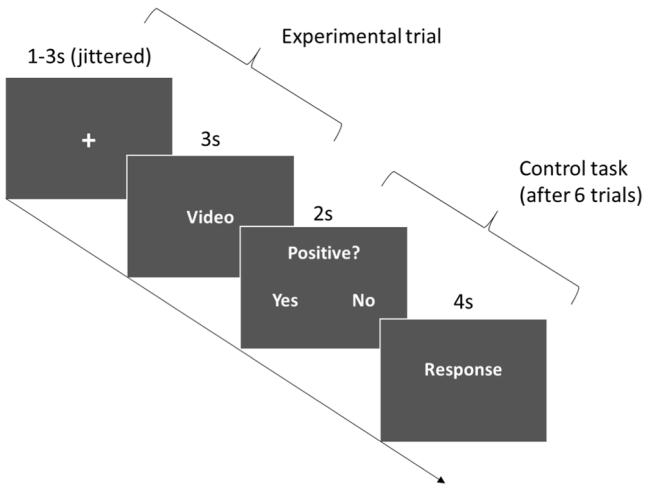

Fig. 1. Example of a trial structure of the passive viewing task.

Phase III: Self-reported measures

In addition to the measures described below, during the week following the EEG recording, mothers completed self-report measures administered via Qualtrics. These included a socio-demographic questionnaire specifically designed to collect basic information, such as age, educational level, occupation, number of children, duration of the couple relationship, as well as the child's sex and age. In cases where both mothers from the same couple participated, each was instructed to complete the questionnaires independently, without consulting their partner. To ensure this, each participant received a separate link and unique access code to complete the questionnaires individually.

Parental involvement in childcare

To assess parental involvement in childcare, we administered an Italian-translated version of the Child Caregiving Involvement Scale, adapted from Wood and Repetti's (2004) work. The items were subsequently back-translated into English. For each of the ten items (Table S2), mothers rated separately (a) their responsibility, (b) their partner's responsibility, and (c) other childcare providers' responsibility (e.g., babysitter). Three total scores, i.e., Involvement (me), Involvement (partner), and Involvement (other), were computed. The items assess both indirect (e.g., making child-care arrangements, coordinating or planning child-related activities) and direct involvement in childcare (e.g., playing or reading to a child, staying home with a sick child). Each item was rated on a 5-point response scale, ranging from 1=*none or very little responsibility* (<10 %), 2=*some responsibility* (10 %–40 %), 3=*about half of the responsibility* (40 %–60 %), 4=*much responsibility* (60 %–90 %), to 5=*almost complete or complete responsibility* (90 %–100 %). Given the objectives of the present study, we used only the score relating to Involvement (me). Cronbach's alpha for this scale was satisfactory (α = 0.86). The Intraclass Correlation Coefficient (ICC) between mother's self-assessment and her partner's perception of her involvement was 0.555 (95 % CI = 0.249–0.760, p = .001), indicating a moderate and statistically significant level of agreement.

Statistical analyses

Descriptive statistics were run on the data to examine mean scores, frequencies, percentages and distributions. Missing data were not replaced. Accuracy in catch trials was 78 %, which indicated a good level of attention while performing the task. Normality assumptions were checked using the Shapiro-Wilk test. A 2 × 2 Repeated-Measure ANOVA with familiarity (own vs. other) and interaction type (successful vs. unsuccessful) as within-subjects factors was first implemented on LPP amplitude. Parent age and child age were considered as covariates. The Variance Inflation Factor (VIF) values for these continuous variables were 1.6, indicating low multicollinearity. Effect sizes were presented as generalized eta squared (η^2G). Post hoc comparisons were corrected with Bonferroni method. Next, two differential LPP scores were computed to check for the confounding effect of the context familiarity in both own and other conditions. The differential scores were computed as follows: ΔLPP(own) = meanLPP [own-unsuccessful] - meanLPP [own-successful]; ΔLPP(other) = meanLPP [other-unsuccessful] - meanLPP [other-successful]. A mixed ANOVA with familiarity (own vs. other) and involvement score as independent variables was computed on the ΔLPP amplitude. Involvement was first entered in the model as a continuous variable. Although it did not meet the normality assumptions

using the Shapiro-Wilk test (Table S4), the values of skewness (0.9) and kurtosis (−0.2) were considered acceptable to prove a normal univariate distribution of the variable. To improve the interpretability of the effects, the involvement variable was split into two levels (i.e., higher involvement vs. lower involvement) by using the median score of participants. Subsequently, we reran a mixed ANOVA with familiarity (own vs. other) and involvement (higher involvement vs. lower involvement) as independent variables on the ΔLPP amplitude. Effect sizes were reported as η^2G. Post hoc comparisons were corrected with Bonferroni method. Finally, Spearman correlation analyses were computed to examine the relationships between the ΔLPP (own) amplitudes and maternal EA scales.

Results

Preliminary analysis

From the total sample of mothers (N = 32), all participants completed the self-reports. However, only 31 mothers were included in the Emotional Availability Scale (EAS) coding, as one mother was excluded for speaking a non-Italian language during the interaction. For the ERP analyses, 22 mothers were considered, with 10 mothers excluded for the following reasons: 1) Excessive artifacts in the EEG data (>20 % of noisy epochs; $n = 2$); 2) Technical problems during the signal acquisition (n = 5); 3) Health conditions that made EEG registration unfeasible ($n = 1$); 4) Not meeting study criteria ($n = 1$ excluded due to pregnancy between Phase I and Phase II); 5) Inability to attend the laboratory for EEG recording (n = 1). The characteristics of the study participants are summarized in Table 1, which also included the number of incomplete cases for each variable. We compared sociodemographic characteristics (e.g. child age, parent age and parity) between mothers who completed the entire protocol and those who did not. Results showed non-significant results for all variables — child age, ($t(29) = 0.16$, $p = .878$, parent age, ($t(29) = -0.56$, $p = .583$ and parity $\chi^2(1,31) = 0.03$, $p = .853$. A representative Grand Average LPP waveform is displayed in Fig. 2.

Main analysis

The 2 × 2 Repeated-Measure ANOVA on the LPP yielded a statistically significant effect of familiarity ($F(1,21) = 15.6$; $p < .001$; $\eta^2G = 0.3$). Post-hoc analyses indicated that the interactions involving the mother's own child elicited a larger LPP amplitude compared to the interactions involving other parent-child dyads ($t(21) = -4.0$; $p < .001$). This effect remained stable after controlling for parent and child age ($F(1,21) = 15.6$; $p < .001$; $\eta^2G = 0.3$). Neither a main effect of interaction type nor an interaction between familiarity and interaction type was statistically significant. Parent age and child age did not show significant effects. Detailed numerical values from the ANOVA are presented in Table 2.

The mixed ANOVA on ΔLPP showed a significant interaction effect between involvement and familiarity ($F(1,20) = 7.7$; $p = .01$; $\eta^2G = 0.2$). This result was confirmed after splitting the involvement into two levels ($F(1,20) = 5.0$; $p = .04$; $\eta^2G = 0.1$). Full numerical values are reported in Table 3, and a graphical representation of this interaction effect is displayed in Fig. 3. Specifically, mothers with higher involvement scores displayed an increased ΔLPP in response to interactions with their own child compared to other parent-child dyads. In other words, mothers who showed higher involvement scores displayed an increased LPP activation to unsuccessful interactions with their own child. In contrast, more involved mothers showed a lower ΔLPP in response to other parent-child interactions, with higher LPP amplitudes for successful compared to unsuccessful interactions. However, these results did not reach statistical significance in post-hoc analyses.

Furthermore, Spearman correlation analyses revealed significant positive correlation between ΔLPP (own) amplitude and maternal sensitivity ($r = 0.5$, $p = .01$), non-intrusiveness ($r = 0.6$, $p = .002$), and non-hostility ($r = 0.5$, $p = .04$). This indicates that mothers with higher levels of sensitivity, non-intrusiveness and non-hostility showed enhanced LPP amplitude in response to the unsuccessful (versus

Table 2
Results of the Anova on the LPP amplitude. df=degree of freedom; η^2G=generalized eta squared. $N = 22$ mothers.

Effects	*df*	*F-value*	*p-value*	*η^2G*
Familiarity	(1, 21)	15.6	0.0007***	0.3
Interaction type	(1, 21)	1.9	0.2	0.008
Familiarity*Interaction type	(1, 21)	0.7	0.4	0.01

*Note. *** = p < .001; ** = p < .01; * = p < .05*

Contrast	***Estimate***	***SE***	***df***	***t ratio***	***p-value***
Other-own	−0.6	0.2	21	−4.0	0.007**

*Note. *** = p < .001; ** = p < .01; * = p < .05.*

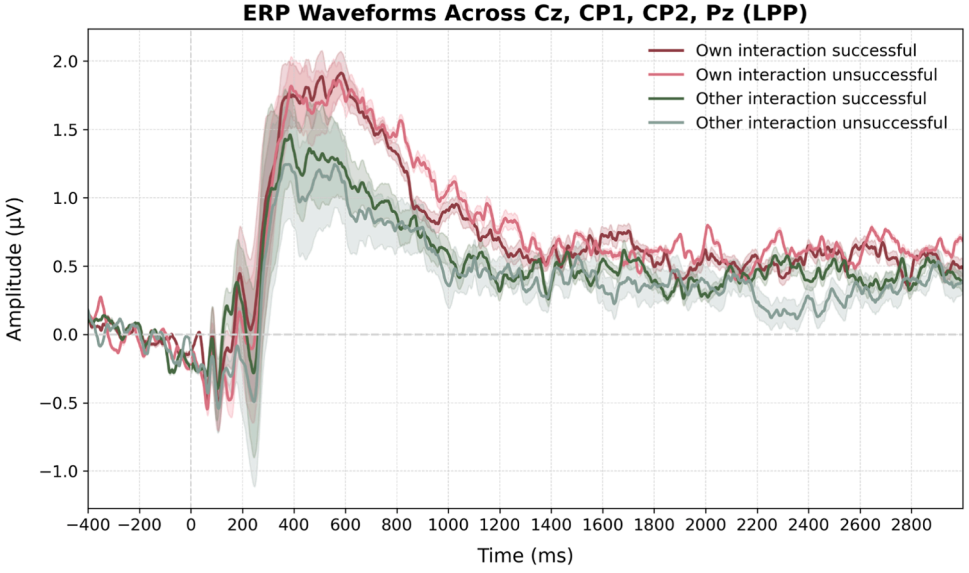

Fig. 2. Grand-average of the LPP component in response to the different conditions. Amplitude (mv) is reported in the y axis. Latency (ms) is reported in the x axis. N = 22 mothers.

Table 3
Results of the Anova on the ΔLPP amplitude. df=degree of freedom; η2G =generalized eta squared. $N = 22$ mothers. ΔOther and ΔOwn refer to the difference between unsuccessful and successful interaction. (Higher) and (lower) refer to the level of the mother's involvement in childcare.

Effects	*df*	*F-value*	*p-value*	η^2G
Familiarity	(1, 20)	0.9	0.4	0.03
Involvement	(1, 20)	1.9	0.2	0.03
Familiarity*Involvement	(1, 20)	5.0	0.04*	0.01
Note. *** = $p < .001$; ** = $p < .01$; * = $p < .05$				
Contrast	***Estimate***	***df***	***t***	***p-value***
ΔOther (higher) - Δown (higher))	−0.5	20.0	−2.3	0.2
ΔOther (higher) - Δother (lower))	−0.2	35.6	−1.1	1.0
ΔOther (higher) - Δown (lower)	−0.03	35.6	−0.2	1.0
ΔOwn (higher) - Δother (lower)	0.3	35.6	1.7	0.6
ΔOwn (higher) - Δown (lower)	0.5	35.6	2.6	0.08
ΔOther (lower) - Δown (lower)	0.2	20.0	0.8	1.0

Note. *** = $p < .001$; ** = $p < .01$; * = $p < .05$.

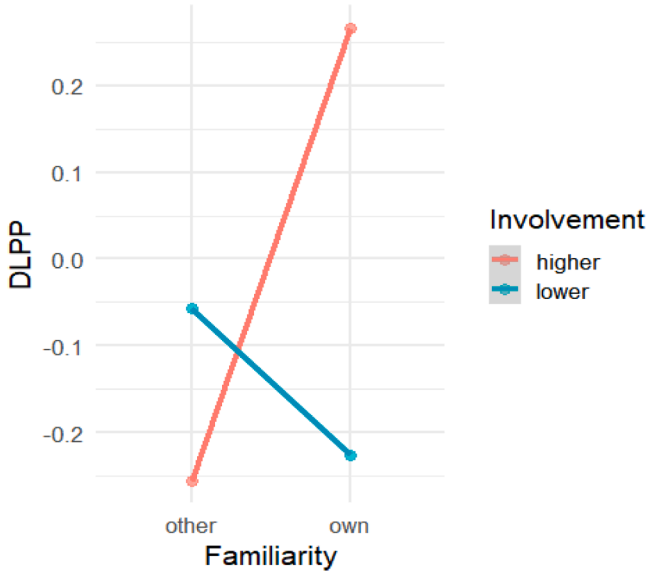

Fig. 3. Interaction effect between familiarity and involvement on the ΔLPP amplitude. $N = 22$ mothers.

successful) interactions with their own child. Rho and p values of these correlations are reported in Table 4. Scatterplots of the significant correlations are displayed in the Supplementary Materials (Tables S1-S3).

Discussion

The current study, to the best of our knowledge, is the first to investigate the ERP responses to mother-child interactions in a sample of same-sex mothers. Using a multi-method research design, it contributes to the field of the neural correlates of parenting moving beyond a heteronormative perspective. These findings enrich previous literature on ecological and dynamic parent-infant exchanges, offering unique evidence on the ERP responses to parent-child interactions within the understudied population of same-sex mothers.

Table 4
Correlations between the EA dimensions and ΔLPP(own). $N = 21$ mothers.

EA dimensions	*rho value*	*p value*
Sensitivity	0.5	0.01*
Structuring	0.4	0.06
Non-Intrusiveness	0.6	0.002**
Non-Hostility	0.5	0.04*
(child) Responsiveness	0.3	0.2
(child) Involvement	0.3	0.3

Note. LPP: Late Positive Potentials; EA: Emotional Availability.
*** = $p < .001$; ** = $p < .01$; * = $p < .05$.

ERP response

We found that the LPP amplitude was larger in response to mothers' interactions with their own child compared to other parent-child interactions. In line with prior research (Bornstein et al., 2013; Bernard et al., 2018), we observed a sustained attentional response linked to the familiarity effect of stimuli involving their own child in same-sex mothers. A specific neural activation in response to interactions with their own child, as opposed to interactions involving other parent-child dyads, may arise from the unique affectional bond between mother and child, as well as its profound social, affective, and personal significance (Rigo et al., 2019). This distinct bond extends beyond the influence of the physical attributes associated with the baby schema (Kuzava, 2021). Consistent with this argument, this effect remained robust, in our study, after controlling for child age. Unlike previous studies, we examined the electrophysiological response of mothers while exposed to dynamic videos of mothers interacting with their children, which represent more naturalistic stimuli, rather than focusing on static pictures of children. As suggested by previous research (Wan et al., 2014) this may constitute a considerable strength of our study, since infant static stimuli do not capture the dynamic nature of parent-child interactions characterized by changes in dyadic synchrony, emotional expressions and intensity. This evidence, overall, could enrich previous literature about the significance of parent-child interactive exchanges, as they are related to a specific pattern of maternal neurobiological responses (Xu & Groh, 2023). Of note, we did not find any effects of the type of interaction (successful vs. unsuccessful) on the LPP amplitude. This may align with previous evidence suggesting that the modulation of LPP amplitude is influenced by the participants' affective social context which, in some cases, may exert a greater impact on the LPP amplitude than the emotional valence of the experimental stimuli (Schiano Lomoriello et al., 2022).

ERP response and maternal involvement in childcare

Another objective of our study was to explore the associations between the LPP amplitude and maternal involvement in childcare. Initially, we found an association between the degree of maternal involvement in childcare and ΔLPP amplitude in response to interactions with their own child. To further explore this relationship, we divided the sample into mothers with higher and lower caregiving involvement. Subsequently, our findings showed that mothers who scored higher in caregiving involvement displayed an increased LPP activation to unsuccessful interactions with their own child and lower LPP in response to the interactions with other children. Although these differences did not reach statistical significance after correction - likely due to the relatively small sample size - the observed trend might suggest a potential influence of caregiving involvement, as an experience-based factor, on maternal neural processing of salient emotional stimuli in the context of their own and other mother-child dyadic interactions. This is particularly relevant, as the ability to identify a child's negative signals and repair interactive ruptures during dyadic exchanges is a key component of maternal sensitivity (Ainsworth et al., 1978). This mechanism also fosters self-regulatory skills and a sense of efficacy in the child, who can be recognized as an active contributor to the dyadic interactions (Tronick et al., 1978; Conradt & Ablow, 2010). Furthermore, the heightened responsiveness of more involved mothers to their own unsuccessful interactions may suggest that caregiving experience contributes to the functional significance of the adult-child selective attachment relationship. In the context of interactive ruptures with their own child (e.g., the unsuccessful interactions), the activation of the attachment-caregiver system may serve to reduce the physical or emotional distance between the adult and their specific child.

The lack of significance after correction may be explained not only by the small sample size but also by the limitations of the measure used to assess involvement in childcare. This scale (Wood & Repetti, 2004) was developed based on a sample of different-sex two-parent families (131 mothers and 98 fathers), which may not fully capture variations in caregiving across more diverse family structures. Moreover, this lack of a statistically significant result might also be consistent with previous findings reporting no association between caregiver commitment and P300 amplitude responses in mothers (Grasso et al., 2009). A possible explanation could be that maternal neural responses may be influenced by various factors beyond the level of commitment. Future research could examine both the amount of time spent with the child and the quality of childcare activities, while considering variations in types of caregiving involvement. Indeed, caregiving processes encompass a variety of behaviors and activities (e.g., feeding, comforting, etc.…) that may uniquely influence maternal responses, providing a broader understanding of the nuances of parenting dynamics. Moreover, the use of qualitative and observational methods can help researchers deepen their understanding of this field, as these methodologies may be better suited to capturing the dynamic nature of parental involvement in childcare, as a complex phenomenon involving several dimensions (Rollè et al., 2019). It is worth noting that our preliminary findings suggest maternal involvement may serve as a potential mediating factor in the relationship between familiarity and neural responses to parent-child interactions. Although the current sample size limited our ability to perform formal mediation analyses, which require greater statistical power, this represents a promising avenue for future research. Larger-scale studies could explore whether the degree of maternal involvement mediates the relationship between familiarity and differential LPP responses to successful versus unsuccessful interactions, potentially clarifying important mechanisms underlying the development of parental sensitivity.

ERP response and emotional availability

Mother-child dyads displayed high levels of EA in this study, with their scores similar to those presented in another pilot study on same-sex mothers (Barone et al., 2020). This provides support to the well-established evidence indicating positive mother-child relationships in same-sex mother families (Fedewa et al., 2015; Golombok et al., 2023). Overall, the higher levels of EA shown by mothers in our sample may stem from the unique journey to parenthood experienced by same-sex couples, who actively chose and nurtured their desire for parenthood. This extensive reflective process likely enhanced their capacity for emotional attunement and synchrony with their children.

Notably, we found that higher levels of maternal sensitivity, non-hostility, and non-intrusiveness during the interaction were associated with an enhanced LPP amplitude in response to unsuccessful interactions with their own child. These findings partially align with some previous evidence on parents of different-sex families showing that the adult processing of distressed child signals is related to optimal parenting qualities, including maternal sensitive and responsive behaviors (Rodrigo et al., 2011; Bernard et al., 2015; Kuzava et al., 2019).

The differential pattern of LPP responses—with greater amplitude for unsuccessful versus successful interactions with one's own child—may reflect the unique motivational salience of ruptures within the parent-child attachment relationship. Observing an unsuccessful interaction likely activates caregiving systems aimed at restoring synchrony, thereby enhancing attentional and emotional processing as indexed by the LPP. This interpretation aligns with broader ERP literature indicating that the LPP indexes sustained attention to emotionally and motivationally significant stimuli (Hajcak et al., 2016). Rather than simply tracking emotional valence, the LPP reflects the motivational relevance of stimuli within their context. The LPP is thought to reflect motivated attention, where cognitive resources are automatically directed toward stimuli that are particularly relevant for survival and well-being (Olofsson et al., 2008). In parenting, this mechanism appears to be tuned to child signals that elicit caregiving responses. Doi and Shinohara (2012) found LPP enhancement in response to caregiving-relevant stimuli, and Grasso et al. (2009) showed maternal status modulates neural responses to child cues signaling need. Our findings similarly suggest that unsuccessful interactions with one's own child may prompt neural processes associated with caregiving motivations. In contrast, successful positive interactions, although emotionally rewarding, may not evoke the same sense of urgency required to engage parental caregiving system. This aligns with evolutionary models of parenting, which emphasize heightened parental sensitivity to distress cues (Bowlby, 1969/1982; Swain et al., 2014). Feldman's (2015) bio-behavioral synchrony model similarly proposes that parents are neurobiologically attuned to disruptions in synchrony.

The absence of this LPP pattern in response to unfamiliar dyads supports the role of attachment-specific motivation. Bernard et al. (2018) and Bick et al. (2013) demonstrate that attachment relationships modulate neural responses to child distress, suggesting the LPP may serve as a neural marker of the motivation to repair ruptures within attachment bonds.

Brain reactivity to child distress signals may increase the likelihood that mothers address dyadic misattunements through repairs, which are considered predictors of child security and regulatory capacity (Gianino & Tronick, 2013). However, in our study, the video-clips displaying unsuccessful mother-child interactions did not consistently show children exhibiting overt distress. In this regard, our findings may reflect a pattern of neural activity in response to interactive ruptures including subtle variations of child negative signals, rather than more emotionally intense negative stimuli such as crying or explicit protest from the child. This extends previous literature on processing children's faces in the parental brain, suggesting that maternal neural activation during unsuccessful interactions with their own child might support sensitive, affective and timely caregiving responses. This mechanism could enhance the ability to negotiate conflict with their child through a non-intrusive and non-hostile approach thereby fostering child autonomy and sense of security. Focusing on intrusiveness, our findings contrast with a prior study by Endendijk and colleagues (2018), which highlighted a significant association between increased LPP activity in response to infant faces and higher levels of intrusiveness. The authors interpreted this as indicative of maternal overinvolvement or high monitoring. However, whether larger or smaller LPP amplitudes are adaptive in the context of caregiving behaviors may depend on the demands of each child (Kuzava, 2021). Other methodological differences — such as the use of static images of unfamiliar infant faces — and our sample characteristics, may also account for the differing results. Additionally, the children's age may have played a role, as they show greater autonomy at this developmental stage compared to early childhood. Moreover, the lack of significant results for the structuring dimension may be due to its focus on setting limits in a preventive and protective manner, emphasizing behavior regulation and guidance rather than emotional dynamics or affective states.

Limitations and future directions

The results of this study should be interpreted in light of several limitations, some of which are commonly encountered in research on sexual minority populations (Krueger et al., 2020). First, the observed associations between brain response and parental dimensions (caregiving involvement and Emotional Availability) do not allow for univocal interpretation, as positive parenting may influence parental neurobiology and vice versa. Moreover, the interpretation of these findings is limited by the small sample size and reduced statistical power. Furthermore, recruitment efforts targeting same-sex families in Italy were significantly hindered by the COVID-19 pandemic and existing legal barriers, which may have further restricted participant enrollment in the study. Additionally, the broad age range of the

children reflects the adoption of less restrictive inclusion criteria than in previous studies as a result of recruitment challenges. The limitations of caregiving involvement measures, originally developed for different-sex couples, highlight the need for more valid scales to accurately capture the various domains of involvement across different family structures. Similarly, the absence of measures for other physiological indicators and maternal emotional risks (e.g., depressive symptoms) limits the understanding of the relationship between ERP and maternal behaviors. Previous research has consistently demonstrated that maternal mental health, particularly depression, can significantly influence the quality of caregiving and neural responses to child cues (Rutherford et al., 2016). This limitation primarily resulted from balancing participant burden with our extensive multi-method protocol. Future studies should incorporate comprehensive mental health assessments to better understand how these factors may moderate the relationship between neural processing and caregiving quality in diverse family structures. Furthermore, social dimensions such as stigma and minority stress, which are known to affect same-sex parents (Baiocco et al., 2020) should also be assessed in future studies, to provide a broader understanding of the contextual determinants of parenting. Generally, future EEG studies on parenting are needed to expand the research samples, including more groups from different geographical contexts, as well as low-income and minority families. Finally, longitudinal research across developmental stages could provide valuable insights into the dynamic relationship between neural activations and maternal behaviors.

Conclusion

This study explores the neurobiological mechanisms associated with maternal behaviors, particularly focusing on how brain responses to interactions with their own child are associated with the ability of mothers to consistently provide a responsive and emotionally supportive environment for the child. This preliminary study showed that same-sex mothers exhibited enhanced LPP amplitude when observing videos of interactions with their own child. Furthermore, higher levels of sensitive, less intrusive, and less hostile maternal behaviors were associated with increased LPP activation in response to unsuccessful interactions with their own child. These findings provide new insights into the neural correlates of maternal responses, contributing to the still limited literature on same-sex families. Additionally, this study underscores the importance of addressing the underrepresentation of LGBTQIA+ families in research and policy, particularly in contexts such as Italy (Monaco & Nothdurfter, 2023). Building on this point, greater efforts are needed to ensure their meaningful inclusion in psychological research and social policy. Inclusive research on diverse family structures is essential, as it allows for a broader understanding of parenting determinants and outcomes (Carone e Lingiardi, 2022; Giannotti et al., 2022; Deneault et al., 2024).

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijchp.2025.100612.

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