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Parental Reflective Functioning correlates to brain activation in response to video-stimuli of mother–child dyads: Links to maternal trauma history and PTSD

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ABSTRACT

Parental Reflective Functioning is a parent's capacity to infer mental states in herself and her child. Parental Reflective Functioning is linked to the quality of parent-child attachment and promotes parent-child mutual emotion regulation. We examined neural correlates of parental reflective functioning and their relationship to physical abuse.

Participants were mothers with (n = 26) and without (n = 22) history of childhood physical abuse. Parental reflective functioning was assessed by coding transcripts of maternal narrative responses on interviews. All mothers also underwent magnetic resonance imaging while watching video clips of children during mother-–child separation and play.

Parental reflective functioning was significantly lower among mothers with histories of childhood physical abuse. When mothers without history of childhood physical abuse watched scenes of separation versus play, brain activation was positively correlated with parental reflective functioning in the ventromedial prefrontal cortex, and negatively associated with the dorsolateral prefrontal cortex and insula. These associations were not present when limiting analyses to mothers reporting abuse histories.

Regions subserving emotion regulation and empathy were associated with parental reflective functioning; yet these regions were not featured in maltreated mothers. These data suggest that childhood physical abuse exposure may alter the psychobiology that is linked to emotional comprehension and regulation.

1. Introduction

Mentalization is the capacity to infer mental states in self and other (Luyten and Fonagy, 2015). As such, mental states encompass emotions, needs, intentions, and desires that can motivate behavior (Frith and Frith, 2006). Mentalization has been operationalized as “reflective functioning” and can be quantified using a coding scale to rate adult narrative responses to semi-structured interviews such as the Adult Attachment Interview (AAI, Main et al., 2003). Interviews such as the AAI probe for the individual's mental representations of his or her primary attachment figures during childhood. Reflective functioning specifically codes the metacognitive process or self-monitoring of the narrative rather than the content (Basnakova et al., 2014).

Greater mentalization and higher reflective functioning have been shown to be significantly associated with attachment security (Fonagy et al., 1991) and emotion regulation in adults (Sharp et al., 2011). Reflective functioning has also been identified as a marker of attachment security and, as such, a protective factor in a number of high-risk populations: for example, foster-care children who have been exposed to parental substance abuse (Ostler et al., 2010) and adolescents with childhood histories of sexual abuse (Ensink et al., 2017). An additional study showed that the degree of reflective functioning mediated the relationship between childhood maltreatment and subsequent expression of violent behavior in adolescence (Taubner et al., 2016).

While adult reflective functioning is coded from semi-structured

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clinical interviews such as the AAI that probe for mental representations of past attachment figures and relationships with those attachment figures, "parental reflective functioning (PRF)" is coded from semi-structured interviews that examine, rather, the parent's present relationship with her own child (Slade et al., 2005). PRF is thus similarly measured using a quantifiable coding scale applied to a parent's narrative responses to semi-structured interviews that probe for her mental representations of her child and relationship with her child.

Parental reflective functioning has been shown to be a protective factor in parent-infant relationships as it is strongly associated with if not a marker of attachment security and organization, and has been associated with greater maternal sensitivity (Berthelot et al., 2015; Grienenberger et al., 2005; Schechter et al., 2005), and to parental and mutual parent-child emotion regulation (Heron-Delaney et al., 2016; Suardi et al., 2018). Parental reflective functioning also contributes to the development of emotion regulation in infants and young children (Heron-Delaney et al., 2016; Suardi et al., 2018), a demonstrated predictor of school-readiness (Russell et al., 2016). Higher parental reflective functioning has also been associated with lower severity of child emotional and behavioral dysregulation (Suardi et al., 2018). The neural correlates of parental reflective functioning have not been previously examined, to our knowledge.

1.1. Neural correlates of RF and PRF related concepts

Several papers have examined the neural correlates of adult (i.e., non-parental) mentalization (Frith and Frith, 2006). Multiple studies have suggested that activation of the dorsal- and ventral-medial prefrontal cortex (dm- and vmPFC) play a significant role in mentalization, even though these two distinct regions of the mPFC subserve different functions (Moriguchi et al., 2006; Schnell et al., 2011; Sebastian et al., 2011).

The concepts of empathy and mentalization are highly related seeing as the former construct encompasses the latter. Both mentalizing and empathy require understanding the mental state of another person; yet, empathy additionally necessitates feeling the emotional experience of the other person while recognizing that that emotional experience is distinct from one's own at the time when empathy is exercised (Decety and Jackson, 2004; Sharp et al., 2013): Several studies have also found an association between empathy, as such, and activity of the dm-and vmPFC, superior temporal sulcus, temporal poles, somatosensory related cortices inferior frontal gyrus and thalamus (Hooker et al., 2008; Kral et al., 2017; Zaki et al., 2009).

1.2. Neural correlates of post-traumatic stress disorder (PTSD)

Among interpersonal violence and combat exposed patients with posttraumatic stress disorder (PTSD), functional neuroimaging studies have found significantly less dm- and vmPFC activity in response to trauma-salient stimuli (Milad et al., 2005; Shin et al., 2006). Similarly, an increase in vmPFC activation was recently found among PTSD patients following Prolonged Exposure Therapy (Foa et al. 1999; Fonzo et al., 2017). Of note, this form of psychotherapy is one of the most commonly used evidence-based treatments for interpersonal violence-related PTSD.

In at least two studies, parental interpersonal violence-related PTSD both categorically (i.e., by diagnosis compared to non-PTSD controls) and continuously (i.e., as measured across the entire sample including diagnosis, sub-threshold, and non PTSD), has been associated with lower vmPFC and dmPFC activity and increased entorhinal, parahippocampal and hippocampal activity in response to video-stimuli of mother–separation vs. play (Schechter et al., 2017). This "corticolimbic dysregulation" has been thought to mirror psychobiological dysregulation in response to separation stress, and has been show to predict, in a longitudinal model, subsequent child symptoms of increased behavioral dysregulation, separation anxiety, and hypervigilance (Schechter et al., 2017). As in the instance of PTSD, amygdala dysregulation was found to be directly associated with a history of childhood physical abuse (van Harmelen et al., 2013). However, little is known as to how a history of childhood physical abuse affects emotion regulation in the brain, and even less as to how it biologically affects parental reflective functioning.

Key cortical regions including the dm- and vmPFC likely have the following roles: (a) top-down cortico-limbic contextualization and thus, regulation, in response to potential traumatic reminders in patients with PTSD (Piggott et al., 2019; Shin et al., 2001; Zhu et al., 2018) and (b) involvement in both top-down and bottom-up self and mutual emotion dysregulation for mothers and their children in the context of daily interactions within their relationship (Schechter et al., 2017, 2012). Related to this latter point, activation of the vm- and dmPFC may also subserve the application of parental reflective functioning just as they do in relation to self-reflective functioning (Bluhm et al., 2012), which is a potentially protective attachment-based factor in the wake of interpersonal violence exposure. Given mPFC's regulatory function with respect to emotion regulation and downregulation of fear-conditioned responses, one might expect that activation of both of its aspects, namely of the dm- and vmPFC activation would be associated both with interpersonal violence-related PTSD severity and level of maternal parental reflective functioning.

Based on a reading of these three studies, it may well be that childhood history of maltreatment leads to adverse consequences on cortico-limbic regulatory activity in the brain over the course of development. One possible outcome could be impairment in the maltreated parent's capacity to appraise child emotional communication in situations reminiscent of painful childhood memories. However, this remains speculative.

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With the aforementioned review of pertinent literature in mind, we wanted to test the hypotheses that parental reflective functioning would be associated with the following:

(1) increased activity in cortico-limbic regulatory brain areas in both vm- and dmPFC as is found in the literature;
(2) increased activity in other brain areas that have been identified as subserving adult mentalization (i.e., superior and middle temporal gyri, the temporal poles, the somatosensory cortex and the inferior frontal gyrus (i.e., anterior insula, frontal operculum, and Broca's area), and thalamus (Hooker et al., 2008; Schnell et al., 2011; Sharp et al., 2013).

We additionally wanted to test whether:

(1) PRF and corresponding mPFC activity would be greater among mothers without histories of childhood physical abuse than with such histories

We wanted to test these hypotheses within a sample of mothers that included both mothers with histories of interpersonal violence, some with PTSD and some without, as well as mothers with neither histories of interpersonal violence nor PTSD.

2. Methods

2.1. Participants

The present study's protocol was approved by the Institutional (ethics) Review Board of the University of Geneva Hospitals and is in accordance with the declaration of Helsinki. Participant dyads were recruited between 2010 and 2014.

Participants were recruited via flyers that were posted at domestic violence agencies and shelters and at the University of Geneva Hospitals and Faculties of Medicine and Psychology, as well as at community centers, daycares and schools in the metropolitan Geneva area. The study was presented as a "study about the impact of stress on the mother–child relationship." Mothers who expressed interest in participating were screened by phone to determine eligibility.

Inclusion criteria stipulated that the participant parent must be the biological mother of her child and have lived with her child. Children were required to be 12–42 months of age at the time of the videotaped mother–child behavioral observation. Participants had also to be fluent in French or English. Exclusion criteria included that mothers not be actively psychotic or substance abusing and that mothers and their children must not be physically or mentally impaired in such a way that would prohibit full participation in study tasks.

Data from participant dyads included videotaped maternal interview, mother–child observations, and an fMRI scan. The videotaped mother–child observations were used to create the stimuli shown to participant mothers in the fMRI scan.

2.2. Sample description

This study was nested in the larger Geneva Early Childhood Stress Project (n = 99, out of which 15 dyads were excluded due to mothers having PTSD related to non-violent trauma, leaving n = 84). Of these 84, the narrative responses to the WMCI of 60 participant mothers who had provided written consent and had completed fMRI scanning were coded for PRF in accordance with our a-priori hypotheses, power-analysis, and funding objectives. Out of these 60 who had completed fMRI scanning, 48 had both complete and trustworthy non-MRI data as well as usable fMRI data. Nine mothers had to be excluded due to lacking quality of fMRI data or not having completed a T1 scan, while 3 were excluded due to incomplete or self-contradictions in the non-imaging data. Results from these 48 mothers are reported in the present study.

2.2.1. Mothers

Among the 48 mothers who participated and had complete and usable data, the majority 62.5% (n = 30/48) were married and 53% (n = 27) were employed at the time of their participation; and 70.4% (n = 34) had at least 4 years of high school education. The large majority (35/48) of mothers were of European origin (i.e., primarily Swiss or French), of African origin (4); while 4 mothers were of other or mixed origin. Among all participants, 26 mothers had experienced childhood PA (17 IPV-PTSD, 9 non-PTSD) and 22 had not (9 IPV-PTSD, 13 non-PTSD). Of the 17 mothers who had IPV-PTSD and childhood PA, 11 also experienced physical and/or sexual assault as adults as contrasted with 6 non-PTSD mother with history of childhood PA. Two of 13 non-PTSD mothers who did not have child PA experienced physical and/or sexual assaults as adults; and 3 out of 6 non-PTSD mothers who had PA, also experienced physical and/or sexual assault as adults. Data from those mothers who were not included in the sample for one reason or another did not differ significantly from those of mothers who were included with respect to maternal age (non-included mothers mean = 35.3 years SD = 6.1, included mothers mean = 33.6 years, SD = 5.4), education (69.4% had at least 4 years of high school), marital status (61.2% were married), employment status (66.7% were actively employed), or national/ethnic origin (80.3% were of European-Caucasian or mixed background), and maltreatment status (53% had experienced physical abuse during childhood). Mothers who were not included in the sample did however include a disproportionate percentage of women suffering from PTSD (80.4%). This may be partially due to the fact that women with PTSD caused by non-violent life experiences were excluded from the present analysis."

2.2.2. Children

Among the 48 children who appear in the video stimuli, the mean age was 27.75 months (*SD* 8.2) and 48% (n = 25) were boys and 52% (n = 23) girls. There were no significant group differences in age, gender, or birth order when groups were defined either by childhood history of PA. Children of mothers who were not included in the study also did not differ from those included with respect to age (mean: 26.34 months, SD = 8.4) and sex (non-included: 45% boys).

2.3. Procedure

As described previously (Schechter et al., 2015), mothers and children participated in videotaped interviews and behavioral observations within 1 month of the screening visit.

During the 1st visit, mothers were interviewed about their mental representations of their child and their relationship with their child. Mothers then completed measures pertaining to their experience of a range of stressful life-events followed by structured psychiatric diagnostic interviews and a series of self-report questionnaires.

The 2nd visit, 2–3 weeks later, involved mothers' participation with her child in a parent-child interaction procedure ("Modified Crowell Procedure," Zeanah et al., 2000). After this interaction procedure, mothers completed questionnaires about their child's socio-emotional development, life-events, attachment and psychopathology (i.e., symptoms and behaviors). Mothers received 50 Swiss francs (roughly equivalent to $50) and a small toy or book for their child was offered for the participation in these 2 visits.

Mothers willing and eligible to participate in the fMRI study were invited to a third visit 2–3 weeks later, for which they were reimbursed with 200 Swiss francs (roughly equivalent to $200).

2.4. Measures

2.4.1. Parental Reflective Functioning (PRF)

PRF was assessed by coding transcripts of maternal narrative responses to the Working Model of the Child Interview (WMCI; Zeanah et al., 2000), which is a semi-structured interview assessing the caregiver's mental representations of her child and her relationship with her child. The WMCI version that was created with additional probes for mentalization, as approved by the WMCI authors, was used so as to permit effective PRF coding of maternal narrative responses. This application of the WMCI is similar to those given in response to the Parent Development Interview (PDI) Revised Version (Slade et al., 2003), which can be coded via the PRF-PDI coding scheme (Slade et al., 2005).

For the purposes of PRF-PDI coding, videotaped interviews of the WMCI were transcribed. The PRF-PDI coding scale is a well-validated and reliable measure of parental child-focused mentalization (Schiborr et al., 2013). PRF was scored from −1 to 9. PRF was independently coded by two clinically-experienced psychologists (co-authors SF and ARS) who were blind to the participant characteristics and who had been trained to reliability. Inter-rater reliability computed for n = 13 cases (23% of the sample) was excellent (ICC = 0.92).

2.4.2. Maternal Life-events and IPV-PTSD

Maternal Life-events experiences and Interpersonal Violence

Exposure were assessed through two questionnaires: The Brief Physical and Sexual Abuse Questionnaire (BPSAQ; Marshall et al., 1998) and the Traumatic Life Events Questionnaire (TLEQ; Kubany et al., 2000). The BPSAQ, a detailed retrospective semi-structured clinical interview, was used in order to quantify the different types and severity of maternal interpersonal violent trauma history from childhood (ages 0-16 years of age) through adulthood (>16 years of age; Schechter et al., 2005). In addition to asking about interpersonal violent events such as physical and sexual abuse and family violence exposure, the BPSAQ probes the age of onset and offset, frequency and chronicity of the experiences, the degree of injury, proximity of relatedness to perpetrator, and other factors. The measure has shown reliability in predicting clinician rated PTSD in two separate studies (Marshall et al., 1998; Schechter et al., 2005). The TLEQ was additionally administered to assess further life-events that were not already covered by the BPSAQ, yet that could fulfill the A-criterion for the PTSD diagnosis according to the DSM-IV.

Maternal Posttraumatic stress disorder (PTSD) was assessed via diagnostic interviews through the Clinician Administered PTSD Scale (CAPS; Blake et al., 1995) and the Post-traumatic Symptoms Checklist-Short version PCL-S (Weathers et al., 2001) to assess current PTSD symptoms. Only PTSD related to interpersonal violence was included in the study. While PTSD symptoms due to any other type of traumatic event were measured; as it happened in this sample, all mothers with the diagnosis of PTSD and with subthreshold symptoms declared that the traumatic event meeting the DSM-IV “A-Criterion” was one of IPV. Consideration of both CAPS and PCL-S scores were involved in continuous analyses.

2.5. Data analysis

Preliminary correlations and Student t-tests were run to establish background relationships between PRF and groups of mothers with and without histories of childhood physical abuse and interpersonal violence-related PTSD.

2.6. MRI session

fMRI stimuli were drawn from mother–child interaction sequences of free-play and separation that had been part of the filmed 25-min mother–child interaction procedure (i.e., Modified Crowell Procedure, Zeanah et al., 2000). A research assistant who was blind to case-control status selected the silent film excerpts for the fMRI stimulus of play (i.e., non-stressful condition) and separation (i.e., stressful condition): mothers viewed the play-excerpt that was rated most joyful and reciprocal, and the separation-excerpt rated most emotionally negative and distressed. As described previously, mothers viewed 6 silent, 30-s video-excerpts of 3 children, each during the two conditions of play and separation: (1) own child, (2) unfamiliar boy, and (3) unfamiliar girl. The unfamiliar children conditions were obtained by filming two non-participant mothers and their children for which mothers had given written informed consent for their videos to be used in the experiment and related presentations to professional audiences. The order of presentation was pseudo-randomized across both blocks and participants. The fMRI study design was described in a previous publication (Schechter et al., 2015).

All data including maternal interview, parent-child observation and symptom scales were collected over a period of 4-6 weeks.

2.7. MRI analysis

In first-level fMRI analysis, we produced a contrast between the average neural activity in response to seeing separation among all children (i.e., own child, unfamiliar boy and girl; which were shown to mothers in a randomized, mixed sequence of stimuli) as compared to play. In order to increase reliability of the data, we took the sum of the average neural activity from seeing unfamiliar children during separation and the average neural activity when mothers saw their own child during separation. From that sum, we subtracted the sum of the average neural activation when mothers saw unfamiliar and own children during play. In order to test the correlation between the contrast of separation vs. play and PRF, we performed a second level analysis that consisted of a general linear model of this contrast with the PRF score as a covariate. To determine whether both own and unfamiliar child conditions contributed to the findings, we then post-hoc also performed similar correlations with parental reflective functioning for own separation vs. own play and unfamiliar separation vs. unfamiliar play in each significant cluster. Following this, we performed a correlation of PRF with neural activation in the separation vs. play contrast once among the PA- mothers and once among PA+ mothers. For each of these two analyses, we then post-hoc extracted the correlation value of the average activation with PRF in each significant cluster. In order to be able to further the understanding of whether these clusters would be similar in the other group we always also performed the latter procedure for the both groups in either analyses.

In line with our previous research, we performed 2nd level analyses using a threshold of uncorrected $p < .005$ with a cluster size of 27 or more, which had previously been tested with a Monte Carlo simulation to yield a 5% probability of false positive clusters. However, in response to concerns about type I errors (Eklund et al., 2016), we confirmed all our initially significant clusters by feeding them into the toolbox SnPM (Gutierrez-Barragan et al., 2017) and applying 10,000 permutations using nonparametric statistics at a cluster forming threshold of $p < .05$.

3. Results

3.1. Correlation of PRF with brain activation

The whole brain analysis correlating PRF with the play vs. separation contrast indicated that the dorsolateral PFC (dlPFC), rather than medial PFC (dmPFC), activity was positively and significantly correlated with PRF. Insula and operculum (part of the IFG) and right STG activity was also associated with higher PRF (see Table 1 and Fig. 1). Post hoc analysis for all significant clusters indicated that both the own and unfamiliar child conditions were correlated with parental reflective functioning, except in the right middle temporal gyrus, where both correlations were in the same direction, but only the condition using the mothers own child was significant at an uncorrected level (see Table 1).

Table 1
Correlation of MRI with PRF across all 48 participants

Region	Cluster Size (voxels)	p FWE	Peak voxels MNI coordinates *x*	*y*	*z*	*t*-value	Correlation with (*r*-value) PTSD Symptoms	PRF	PRF Own only	PRF Unfamiliar only
Association with play > separation (own and unfamiliar combined)										
R dorsolateral prefrontal cortex	35	0.0001	21	53	25	4.54	−0.26	0.52	0.45	0.40
L dorsolateral prefrontal cortex	31	0.0001	−15	14	64	4.07	−0.04	0.53	0.38	0.36
L operculum/insula	38	0.0001	−57	14	19	4.05	−0.07	0.53	0.32	0.38
R middle temporal gyrus	37	0.0001	48	−22	−11	3.79	-0.09	0.53	0.54	0.31

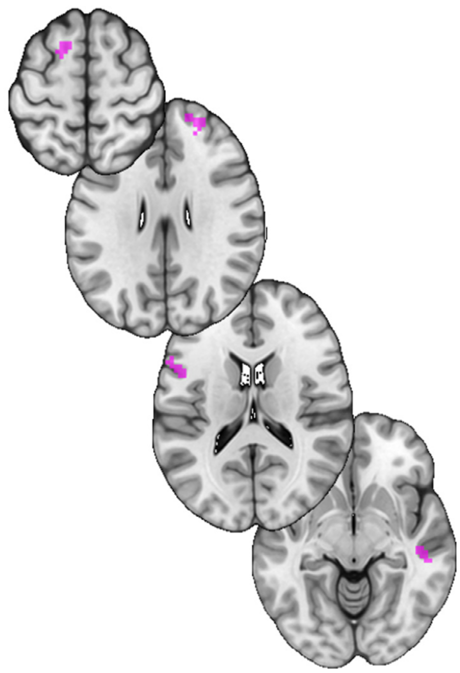

Fig. 1. Brain regions where parental reflective functioning correlated significantly with maternal brain activation when watching children during separation vs. play.

3.2. Correlation of PRF with brain activation among mothers with and without physical abuse

We found that PRF was significantly lower among mothers with histories of childhood physical abuse (RF mean 4.29, *SD*0.96) than those without, (4.79, *SD*0.92): $t(1,60) = 2.10, p < .05$). In this sample, 93% of mothers reported physical abuse by a primary attachment figure: 73% by their biological mother, and 20% by a caregiver who was identified as primary but was not their biological mother (i.e., grandmother, aunt, father).

As shown in Table 2a, we found that physically abused mothers showed a significant association between their level of PRF and activity in the following regions in response to play vs. separation: dmPFC, dlPFC, right operculum/insula, right temporal-parietal junction and left superior temporal gyrus (see also Fig. 2). In response to separation versus play among mothers who had not experienced childhood physical abuse, PRF was associated with vmPFC and left middle temporal gyrus activity. None of the brain areas in which PRF correlated with brain activation in non-abused mothers significantly correlated with PRF in the abused mothers. Only in vmPFC did PTSD symptom severity also correlate with brain activity. This correlation however was exclusive to the non-abused mothers and if anything, in the opposite direction for the abused mothers, with decreased activity in the latter group (see Table 2a and Fig. 2).

As shown in Table 2b among physically abused mothers, PRF correlated with activation of the right thalamus in response to play vs. separation. PRF also correlated with activation of the temporal-parietal junction in response to separation vs. play. None of these associations were present among the non-abused mothers. Caudate activation was negatively associated with PTSD symptom severity among the non-abused mothers.

4. Discussion

To summarize our findings, (1) PRF was associated with greater dlPFC activity rather than mPFC (vm- or dmPFC) activity as we had expected. (2) Both IFG and right STG activity was, nevertheless, associated with higher PRF as expected, given the existing literature. The latter was true both for familiar and unfamiliar child conditions; however, with respect to the right middle temporal gyrus (MTG), only the condition involving mothers' own child was significant at an uncorrected level. (3) As hypothesized, PRF was significantly lower among mothers with histories of childhood physical abuse regardless of mothers' interpersonal violence-related PTSD status. In this sample, over 90% of the mothers who experienced childhood physical abuse stated that their abuse was perpetrated by their primary attachment figure as we had hypothesized. These mothers showed a significant association between their level of PRF and neural activity in the following regions in response to play vs. separation: dmPFC, dlPFC, IFG in the areas of the right operculum/insula, the right temporal-parietal junction and left superior temporal gyrus. Only among mothers who stated that they had not experienced childhood physical abuse (i.e., were likely to have had a better relationship with their primary attachment figure), PRF was positively associated with vmPFC and left middle temporal gyrus activity. None of the brain areas in which PRF correlated with brain activation in non-abused mothers significantly correlated with PRF in the abused mothers. Only in terms of vmPFC activity, did PTSD symptom severity also correlate with brain activity. This correlation however was exclusive to the non-abused mothers and, if anything, in the opposite direction among abused mothers, with decreased activity in the latter group (see Table 2a and Fig. 2).

As shown in Table 2b among physically abused mothers, PRF correlated with the activation of the right thalamus in response to play vs. separation. PRF also correlated with activation of the temporal-parietal junction in response to separation vs. play. None of these associations were present among the non-abused mothers. Caudate activation was negatively associated with PTSD symptom severity among the non-abused mothers.

We wanted to test these hypotheses within a sample of mothers that included both mothers with histories of interpersonal violence, some with PTSD and some without, as well as mothers with neither histories of interpersonal violence nor PTSD.

A main finding of the present study is that the level of maternal PRF across the entire sample in response to the play versus separation contrast was positively and significantly correlated with activity of the bilateral dorsolateral PFC rather than that of the mPFC (dm- and/or vmPFC) as had been expected. The regulatory role possibly played by activation of the dlPFC is important to consider. The dlPFC has been noted to be a key region implicated in emotion appraisal and has been found to be less activated in individuals who are deficient in empathy (Rego et al., 2015). Fear-learning and vulnerability to anxiety due to decreased extinction have been similarly associated with decreased activity both of the mPFC and dlPFC, as well as decreased connectivity between the dlPFC and hippocampus (Ganella et al., 2017). In the latter study, fear-learning and vulnerability to anxiety was associated with decreased connectivity between the mPFC and amygdala, and thus in a second circuit implicated in cortico-limbic regulation.

Additional main findings, however, supported the a-priori hypothesis that PRF would be significantly lower among mothers with a history of childhood physical abuse than those without, regardless of their interpersonal violence-related PTSD status. Of note, in the vast majority of childhood physical abuse cases, the primary attachment figure (i.e., mother, maternal caregiving figure) had been the perpetrator. This latter finding supports the notion that PRF is a probable marker of the quality of the parent's early primary attachments. This would mean that a mother's having had an early attachment to a maltreating primary caregiver would increase the likelihood of her own attachment status being insecure and disorganized (Slade et al., 2005).

In response to the separation (stressful condition) vs. play (non-stressful condition) contrast, PRF was associated with vmPFC activity, an area that subserves emotion regulation, mentalization and empathy among non-abused mothers only. Thus further research is needed to confirm the neural correlates of attachment security and organization

Table 2a
Correlation of separation vs. play contrast with PRF among 22 women who did not report experiencing physical abuse while they were children.

Region	Cluster Size (voxels)	Peak voxels MNI coordinates p FWE	x	y	z	t-value	Correlation with (r-value) PRF	PTSD symptoms
							PA+[1] PA−[2]	PA+[1] PA−[2]
Association with play > separation								
R dorsomedial prefrontal cortex	28	0.027	15	38	46	5.23	−0.05 −0.70	−0.08 0.23
R dorsolateral prefrontal cortex	45	0.012	39	−1	52	4.02	−0.24 −0.66	−0.10 0.19
R operculum /insula	30	0.023	42	2	16	4.37	0.06 −0.71	−0.18 0.22
R temporal-parietal junction	146	0.001	27	−40	31	5.62	0.19 −0.70	0.07 0.11
R premotor cortex	42	0.013	27	2	28	4.49	−0.14 −0.73	−0.10 0.11
R postcentral gyrus	81	0.002	18	−31	64	4.38	0.24 −0.68	−0.06 0.09
Left superior temporal gyrus	28	0.027	−45	−46	10	4.33	−0.24 −0.66	−0.04 0.12
Association with separation > play								
Ventromedial prefrontal cortex	32	0.020	−6	53	−5	4.59	0.05 0.69	−0.30 0.47
L middle temporal gyrus	41	0.013	−63	−46	−14	5.67	0.30 0.65	−0.14 −0.23
R cerebellum	117	0.0004	33	-67	-35	5.27	0.09 0.71	0.01 −0.56
L cerebellum	49	0.010	−39	−55	−44	4.49	0.06 0.68	0.13 −0.34
Cerebellar vermis	28	0.026	3	−55	−26	3.91	0.18 0.64	0.33 −0.41

Clusters of significant correlations of PRF with brain activation representing the Separation vs. Play contrast among 22 women who did not report experiencing physical abuse while they were children. Correlations of PRF within these clusters among women who did experience physical abuse during childhood are given for reference, as are correlations with PTSD symptoms. 1 Correlation of PRF and brain activation among PA+ women ($n = 26$) who reported experiencing physical abuse while they were children, 2 Correlation of PRF and brain activation among PA- women ($n = 22$) who did not report experiencing physical abuse while they were children.

as likely buffers for intergenerational transmission of trauma and related psychopathology via support of self-reflection and emotional regulation that promotes co-regulation during sensitive developmental periods.

The present study also found increased activity in brain areas that have been associated with mentalization, reflective functioning and/or empathy involving two areas that were hypoactive in response to the contrast of separation vs. play: the left operculum/insula which is part of the inferior frontal gyrus, and the right superior temporal gyrus. These two areas are of interest in that the left inferior frontal gyrus, in particular the region of the inferior operculum, has been associated with social reciprocity (Basnakova et al., 2014). The inferior operculum and the right superior temporal gyrus both have been implicated in the perception of emotional communication, in particular, determining where emotion communication by another individual is being directed as a function of social cognition and in this way may explain the relationship to mentalization/reflective functioning (Deen et al., 2015). The right superior temporal gyrus has also been implicated more specifically in the detection of anger prosody and integration of cognitive and emotional aspects of social communication (Green et al., 2013; Sander et al., 2005).

Removing mothers who had a childhood history of physical abuse revealed associations to other areas that are implicated in adult mentalization/reflective functioning studies; namely, the right insula and within the right operculum (as part of the inferior frontal gyrus). These regions had reduced activation in response to the contrast of separation vs. play and have additionally been implicated in sensitive parental response to child emotional communication (Kluczniok et al., 2017). Additionally, the bilateral superior temporal gyrus emerged as hypoactive in response to the separation vs. play contrast, which resonates, albeit unilaterally rather than bilaterally, with a prior study (Nolte et al., 2013). Nolte et al. (2013) employed the “Reading the Mind in the Eyes” task to measure mentalization so as to test the relationship of the response to an attachment -related stress induction versus a general stress induction in relation to social cognition. In this study, reduced mentalization-related activation was found in the left inferior frontal gyrus and superior temporal gyrus, and increased activation found in the left medial temporal gyrus

Of interest, a region that had not been featured in the mentalization literature but which has been noted to be involved in social cognition is the cerebellum (Hoche et al., 2016). More specifically, the bilateral cerebellum and cerebellar vermis were activated in the present study in response to the contrast of separation vs. play. The cerebellum also seems clearly to play some role in emotion regulation and in post-traumatic response as well; although its precise nature in both instances is only beginning to be understood (Rabellino et al., 2018; Turner et al., 2007).

4.1. Limitations

While there is an advantage to using naturalistic film stimuli featuring mothers’ own children in the fMRI task, there is also a limitation to its use. Namely, the task stimuli are quite heterogeneous. This makes it difficult to exclude the possibility of differential effects of the stimuli from one subject to another. Another limitation includes the lack of own vs. other child comparisons as an effort to limit the number of comparisons given the relatively small sample size. Related to this implicit heterogeneity, an additional limitation is that we did not measure birth order of the child subjects. Finally, the Brief Physical and Sexual Abuse Questionnaire which we used to measure different forms of maternal exposure to child maltreatment and other forms of interpersonal violence exposure is a retrospective life-events measure and as

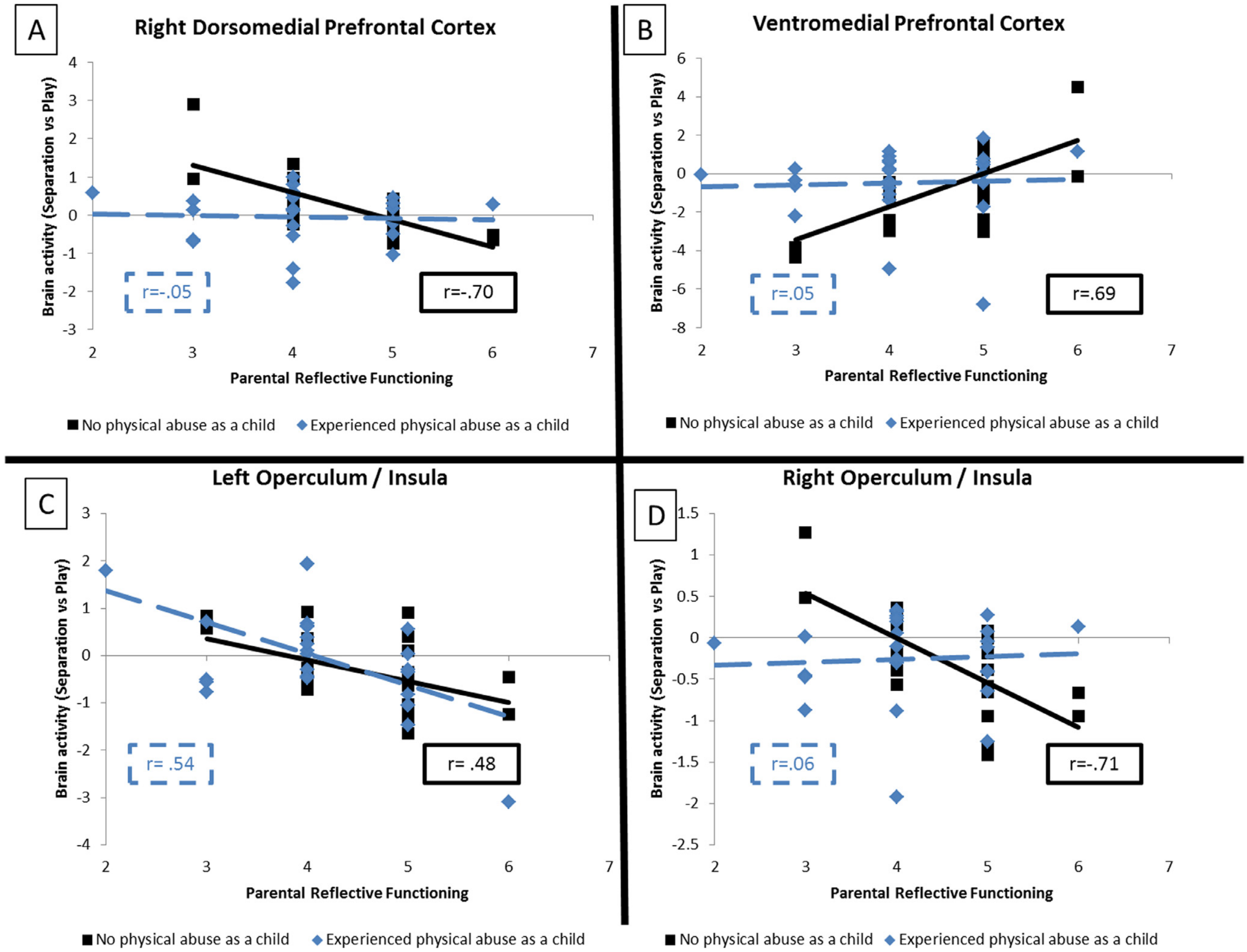

Fig. 2. Selected scatter plots of maternal brain activity correlated with parental reflective functioning. Fit lines for mothers who experienced physical abuse during their childhood are intermittent, fit lines for mothers who reported no physical abuse during childhood are continuous.

Table 2b
Correlation of separation vs. play contrast with PRF among women who reported experiencing physical abuse while they were children.

Region	Cluster Size (voxels)	Peak voxels MNI coordinates p FWE	*x*	*y*	*z*	*t*-value	Correlation with (*r*-value) PRF	PTSD Symptoms
							PA+[1] PA−[2]	PA+[1] PA−[2]
Association with play > separation								
R thalamus-caudate tail	34	0.002	15	−1	7	3.88	−0.63 0.18	0.12 −0.40
Association with separation > play								
L temporal-parietal junction	29	0.003	−30	−55	19	4.54	0.66 −0.18	0.10 −0.28
L cuneus	29	0.003	−12	−88	25	5.21	0.70 0.32	−0.34 −0.24
L cuneus	52	0.0003	−18	−61	16	4.63	0.67 0.05	−0.11 −0.22
L cerebellum	70	0.0001	−30	−34	−29	5.56	0.74 0.18	−0.03 −0.20
L cerebellum	36	0.002	−18	−61	−32	4.42	0.65 0.27	0.24 −0.49

Clusters of significant correlations of PRF with brain activation representing the separation vs. play contrast among women who reported experiencing physical abuse while they were children. Correlations of PRF within these clusters among women who did not experience physical abuse during childhood are given for reference, as are correlations with PTSD symptoms. 1 Correlation of PRF and brain activation among PA+ women with the experience of physical abuse while they were children, 2 Correlation of PRF and brain activation among PA-women without the experience of physical abuse while they were children.

such, involves an increased margin of reporting error compared to a prospective measure. Another limitation of the BPSAQ is that it does not probe adequately for childhood neglectWe thus could not account for the relationship of maternal exposure to child neglect to PRF or maternal neural activity in response to separation vs. play. Future studies might replicate and extend this study, adding measures of neglect and other forms of maltreatment to the existing independent measures

4.2. Conclusion and clinical implications

Activation of some key top-down regulatory areas such as the dm- and vmPFC was associated with the level of maternal PRF and the severity of maternal interpersonal violence-related PTSD in the absence of maternal childhood history of physical abuse. However, this was not the case when mothers with a childhood history of physical abuse were included in the analyses. Rather, the dlPFC, and additional areas that have been shown to subserve adult mentalization (i.e., operationalized as reflective functioning), emotion regulation, and/or empathy, such as the inferior frontal gyrus, insula and superior temporal gyrus, were found to subserve maternal PRF in response to the contrast of mother–child separation vs. play. Maternal interpersonal violence-related PTSD in response to the separation vs. play contrasts has been associated with a different pattern of neural activity: Maternal interpersonal violence-related PTSD has been associated with hypoactivation of the dm- and vmPFC, dorsal anterior and posterior cingulate gyrus, and the hyperactivation of the hippocampus and neighboring para-hippocampal areas (Schechter et al., 2017). In the absence of a maternal childhood history of physical abuse, vmPFC activity was positively correlated with the level of maternal PRF and negatively correlated with the severity of maternal interpersonal violence-related PTSD. Again, of note, among mothers with a childhood history of physical abuse, the dm- and vmPFC do not appear to play any significant role in relation to PRF. Given that perpetrators of childhood physical abuse are often primary attachment figures (Schechter et al., 2017), the fact that among mothers with physical abuse, both reflective functioning and its association with the mPFC are significantly reduced, could potentially mean that these mothers have a different psychobiological lens through which they appraise their young children's emotional signals and the context (i.e., of safety versus danger) in which they are communicated.

We wonder whether activation of the vmPFC and/or dlPFC might be studied in the future to mark a positive response to psychotherapeutic intervention for traumatized mothers that focuses both on supporting and modeling maternal PRF as well as reducing the severity of maternal interpersonal violence-related PTSD. This is based on the idea that emotion regulation strategies may allow improved top-down regulation of the limbic system by the medial and lateral prefrontal cortex. The need for such studies among PTSD patients is high, given evidence that PTSD patients show more bottom-up emotion modulation from the amygdala to prefrontal regions than top-down (Nicholson et al., 2017). Therapeutic approaches have already indicated that decreased limbic (i.e., amygdala) activation can be a marker of therapeutic change (Shou et al., 2017). However, the literature has yet to show whether increased mPFC or dlPFC activation among parents with PTSD following intervention will lead to increased capacity for parent-child emotion regulation or sensitive caregiving behavior.

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Declaration of Competing Interest

None of the authors report any conflict of interest.

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Supplementary materials

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