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Regular Article

Maternal mind-mindedness and infant oxytocin are interrelated and negatively associated with postnatal depression

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Abstract

Previous studies show that maternal mind-mindedness positively impacts children's social development. In the current studies, we examine the relation between mind-mindedness during parent–child interaction, oxytocin (OT), and postnatal depression in a sample of mothers ($N = 62$, ages 23–44) and their infant (ages 3–9 months). In Study 1, infant salivary OT was positively correlated with mothers' appropriate mind-related comments, and negatively correlated (at trend level) with maternal depression scores. Mothers experiencing symptoms of depression used fewer appropriate mind-related comments than controls. Study 2 was a double-blind, placebo-controlled, experimental study, in which the same women who participated in Study 1 were administered nasal OT. This did not significantly influence levels of mind-mindedness. Study 2 warrants a larger trial to investigate the effect of OT on mind-mindedness further. Study 1 is the first to demonstrate an association between maternal mind-mindedness and variation in children's OT levels. Since both OT and mind-mindedness have been repeatedly implicated in processes of maternal–infant attachment, this association highlights the centrality of mothers' caregiving representations in facilitating the parent–child relationship and children's early development.

Keywords: Mentalizing; mind-mindedness; mood; oxytocin; postnatal depression

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Infants communicate their need for adequate care through subtle social cues (Fonagy et al., 2007). The sensitivity of a parent to interpret and suitably respond to these cues, while adapting regularly to meet the infant's evolving needs, is a strong predictor of children's socio-emotional and cognitive development (Raby et al., 2015). A critical element to achieve this is the parent's "mind-mindedness," defined as the caregiver's ability to comprehend their infant's internal states and acknowledge the infant as a distinct entity with independent thoughts and emotions (Meins et al., 2001; Meins, 1997).

Mind-mindedness is part of a broader family of concepts that index "mentalizing" (Fonagy, 1989) – the human capacity to understand oneself and others in relation to intentional mental states (Luyten et al., 2020). This group also includes "reflective functioning" (Fonagy et al., 1991), "theory of mind" (Premack & Woodruff, 1978), the "intentional stance" (Dennett, 1987), and "insight" (Oppenheim & Koren-Karie, 2002). Each of these components has been studied in the context of forming and sustaining social relationships, and mentalizing has been found to be associated with positive mental health outcomes in community populations, and reduced in patients experiencing a range of conditions including depression, anxiety, and personality disorders (Luyten et al., 2020). In this paper, we focus on mind-mindedness as it uniquely assesses the parent's observed understanding of the infant's mental states during parent–child interaction, unlike parental reflective functioning which is measured by interview or questionnaire methods (Meins et al., 2001).

Mind-mindedness is operationalized during caregiver–infant interaction in terms of the caregiver verbally expressing "appropriate" mind-related comments, which accurately represent the child's internal state, or "non-attuned" mind-related comments, demonstrating a lack of understanding or misinterpretation of the child's internal state (Meins et al., 2001, 2012). Appropriate and non-attuned mind-related comments made by the caregiver are unrelated, and therefore do not represent opposite poles of a unidimensional construct. Rather, a caregiver exhibiting mind-mindedness tends to score highly on appropriate mind-related comments, and/or makes minimal, if any, non-attuned mind-related comments. Over time, consistent engagement from the parent displaying suitable responses to the infant's internal state creates a scaffold that assists the child in recognizing and beginning to control their own emotions (Fonagy et al., 2007; Nikolic et al., 2022).

Building on this foundation, children develop intersubjectivity and empathy, acquire the ability to co-regulate interaction with

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others, and cultivate social competence and meaningful understanding of their experiences (Ensor & Hughes, 2008; Feldman, 2010, 2021; Priel et al., 2019; Wright et al., 2018). Supporting this model, parental mind-mindedness has been linked with various positive developmental outcomes in children (Aldrich et al., 2021; McMahon & Bernier, 2017). For example, higher levels of appropriate mind-related comments have been shown to predict secure infant–caregiver attachment, while non-attuned mind-related comments predict insecure attachment (Meins et al., 2012). Parental mind-mindedness during the first year of the infant's life also correlates with the development of children's later social competence and their own mentalizing abilities during preschool years (Colonnesi et al., 2019; Fishburn et al., 2022).

Given the significant implications of these developmental factors on children's mental health and educational outcomes (Bernier et al., 2017; Colonnesi et al., 2019; Meins et al., 2019; Nikolic et al., 2022), it is vital to understand individual variation in parental mind-mindedness. However, despite the past research on parental mind-mindedness, several fundamental questions remain unanswered. In particular, little is known about what makes certain caregivers more mind-minded than others, and through which mechanisms mind-mindedness promotes children's development.

Previous research indicates that a caregiver's tendency to engage in mind-mindedness during interactions with their infant is not related to the infant's characteristics or behavior. For example, mind-mindedness is not related to concurrent infant behavior, vocalization, or general cognitive development (Meins et al., 2001). It is also not associated with infant temperament, whether assessed via maternal report (Meins et al., 2011) or empirical observation (Larkin et al., 2019). Similarly, mind-mindedness is not related to caregiver characteristics such as educational level or socioeconomic status (Bigelow et al., 2015; Laranjo & Bernier, 2013; McMahon et al., 2016; Meins et al., 2011). However, some studies have reported lower levels of mind-mindedness in younger mothers compared to older mothers (Demers, 2010; Larkin et al., 2019). In addition, while research in community samples does not indicate a strong link between mind-mindedness and symptoms of maternal depression (Georg et al., 2023; Meins et al., 2011), severe mental illness is associated with impaired mind-mindedness (Pawlby et al., 2010; Schacht et al., 2017). Furthermore, mind-mindedness correlates with better emotion regulation in infants, as assessed by variations in infants' heart rates (Zeegers et al., 2018), and children's functional connectivity during resting state fMRI at 10 years of age (Dégeilh et al., 2018).

To date, research has predominantly centered on investigating infant and caregiver correlates of mind-mindedness at the demographic and behavioral level. The studies reported here are the first to explore whether individual differences at the hormonal level might explain why some caregivers are more mind-minded than others, and how this relates to the parent–child relationship. Specifically, in Study 1 we investigated the association between maternal mind-mindedness and infant endogenous oxytocin (OT) as a marker of development. In Study 2 we report the effects of exogenous OT administrated nasally in mothers on mind-mindedness experimentally.

Oxytocin and mind-mindedness

OT is a neuropeptide hormone that is naturally produced in both mothers and infants. Higher levels of endogenous OT in mothers have been associated with sensitive caregiving behavior and secure attachment (Feldman et al., 2007, 2012; Strathearn et al., 2009). Maternal OT is also related to increased gaze focused toward the infant by mothers during parent–child interaction (Kim et al., 2014) and greater mother–infant synchrony (Feldman et al., 2011). Since appropriate mind-related comments are positively associated with both caregiver sensitivity and secure infant–caregiver attachment (Meins et al., 2001, 2012), and being aware of the infant's focus of attention and interest likely precedes mind-mindedness, it is reasonable to hypothesize that the OT pathways may be involved in mind-mindedness.

Higher maternal plasma OT levels during the third trimester of pregnancy have also been found to predict a more engaged and relaxed maternal interactive style with their infants at 7 to 9 weeks postpartum, with this effect mediated through maternal theory of mind, as measured by an adult mental state performance test (MacKinnon et al., 2014). Although the ability to interpret others' internal states, provided by theory of mind, is proposed to be necessary but not sufficient for mind-mindedness (Barreto et al., 2016; Devine & Hughes, 2019; Larkin et al., 2021), these results suggest that endogenous OT may be a biomarker of maternal sensitivity toward her infant's social cues.

In support of this, higher endogenous OT levels in both mothers and their child have been associated with increased synchrony of social coordination and engagement during parent–child interaction, and greater social orientation in infants (Clark et al., 2013; Ferera et al., 2023; Priel et al., 2019; Shimon-Raz et al., 2021; Weisman et al., 2012; Zagoory-Sharon et al., 2024). This signals the existence of a two-way process between mothers and infants that involves OT, whereby maternal OT stimulates changes in the neurobiology of caregiving that heightens the mothers' sensitivity to respond to her infant's social cues. In turn, responsive caregiving stimulates the child's own OT, which influences their social orientation.

Maternal OT has also been found to enhance the selectivity of an attachment relationship by increasing the sensitivity of processing specific social information related to a preferred partner, and establishing specific patterns of social response to this partner (Strathearn et al., 2008, 2013). These findings are in line with evidence demonstrating that mind-mindedness only operates within the context of close personal relationships, and does not extend to a general focus on unknown individuals' mental states (Larkin et al., 2021). As such, maternal OT may have an enduring effect that stimulates sensitive caregiving by increasing mothers' mind-mindedness, through enhancing the sensitive detection and accuracy of interpretation of her infant's mental states, while promoting appropriate responses in maternal behavior, and influencing children's development.

In the present paper, we explore this model through two approaches. First, by examining whether higher levels of mind-mindedness in mothers at baseline might relate to infant endogenous OT (Study 1). In addition, in Study 2, we hypothesized that activation of the maternal OT system, by administering exogenous OT experimentally, may stimulate sensitive caregiving in mothers, potentially also through its effects on expanding mothers' mind-mindedness, since for mothers to respond appropriately to their infant's signals, they must first accurately interpret them. This idea is supported by research demonstrating that OT plays a causal role in facilitating social attunement to others. For example, administering exogenous OT has been found to enhance a person's ability to anticipate someone else's behavior (Aydogan et al., 2018), as well as their ability to recognize and interpret the emotional valence of facial and vocal expressions (Domes et al., 2007). OT administration also increases accuracy in

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social perception (De Dreu et al., 2010), facial mimicry (Pavarini et al., 2019), emotional empathy (Hurlemann et al., 2010), and parenting behavior, through vocal synchrony with the infant, positive arousal, and social gaze (Weisman et al., 2014). Since these behaviors are all likely prerequisites for a caregiver's ability to comment in a mind-minded manner on the infant's internal states, the present research therefore also explored whether the OT pathways might explain variation in mothers' mind-mindedness.

Aims and objectives

The primary aim of the current studies was therefore to investigate the relation between maternal mind-mindedness and OT in mothers and their infant. Within the scope of these objectives, we also considered external variables that could impact associations between mind-mindedness and OT. For example, previous studies have identified a relation between postnatal depression (PND) and reduced levels of endogenous OT in both mothers who experienced PND and their children (Apter-Levy et al., 2013). Further, in contexts of early maternal depression, difficulties coordinating behavior during parent–child interaction have been associated with prolonged disruption to OT in both mothers and their child (Priel et al., 2019). Given the correlation between maternal PND and negative outcomes in children's social development (Sanger et al., 2015), and the association between clinical depression levels and reduced mind-mindedness (Schacht et al., 2017), we further evaluated the effects of maternal depression and variation in mothers' mood on the relations between OT and mind-mindedness.

The current studies therefore investigated several key questions. First, in Study 1 we examined the correlation between mothers' mind-mindedness and endogenous OT in their infants, on the assumption that high levels of maternal mind-mindedness promote the infant's OT release. Second, in Study 2 we explored the relation between maternal OT and mind-mindedness experimentally, assessing whether the administration of OT through a nasal spray leads to an increase in mothers' mind-mindedness. Finally, we examined the relations between maternal depressive symptoms and (a) levels of mothers' mind-mindedness and infant endogenous OT in Study 1 and (b) any potential moderating effect of OT administration on maternal mind-mindedness under experimental conditions in Study 2.

Method

Participants and demographics

Sixty-two mothers (M age = 33.58 years, SD = 4.42, age range = 23 to 44 years) and their infants (M age = 4.71 months, SD = 1.69, age range = 3 to 9 months) took part in both studies. Demographic factors were collected through a questionnaire that included maternal age, educational level, marital status, postpartum duration, number of children, nationality, use of birth control, menstrual cycle, duration of gestation, and mode of childbirth. These factors were considered in the analyses as potential confounding variables that could affect maternal mood or OT levels. All mothers were breastfeeding their infants at the time of taking part in the study, either exclusively or in combination with other food, as this was an inclusion criteria for the research. See Table 1 for all participant demographic information. Considering that 79% of the mothers completed education to university level, the sample was considered resourceful in terms of socio-economic status. Mothers were recruited for the study in community settings. Further recruitment details of the sample are reported in Lindley Baron-Cohen et al., 2022. Exclusion criteria included if the mother was younger than 18 years old or pregnant. All participants underwent screening using the Edinburgh Postnatal Depression Scale (EPDS) (Cox et al., 1987) for symptoms of PND. Within the sample, EPDS scores ranged between 0 and 24, with a mean score of 8.35 (SD = 5.80).

Study design and grouping

Data collection for both studies took place under the umbrella of Study 2, that employed a double-blind, placebo-controlled, case-controlled experimental study, in which participants were randomized into a within-subjects, cross-over design. In Study 1, all 62 mothers and their children were observed in a large baseline correlational design. To examine the relations between maternal depression, mind-mindedness and OT for both studies, a case–control design was also used for analysis by stratifying the sample into probable PND cases (n = 26, 42%) and controls (n = 36, 58%), using a cutoff point on the EPDS of ≥9 to determine PND cases. This threshold is consistent with the level recommended for clinical referral of PND in cultural contexts where PND detection rates in community settings are low (Cox et al., 1987; Martin & Redshaw, 2018; NCT, 2017). A power calculation using R software suggested that with n≥24 per group and assuming a medium effect size (d = .54), there would be 75% power to detect a difference between groups, factoring in a 5% Type 1 error. The two groups were matched in terms of infant and maternal ages.

Data collection and experimental protocol

Data collection took place at the research laboratory in central London between 2017 and 2020 at three time points: Baseline (Study 1), and then in Study 2, Condition 1 (post-first nasal administration of either OT or placebo), and Condition 2 (post-second nasal administration of either OT or placebo). The sequence of tasks was kept consistent across all participants for each of the three time points. To start, all participants engaged in a 5-minute naturalistic free-play interaction without toys, which was video-recorded. Following this, at baseline only, infant saliva was collected using cotton swabs provided by Salimetrics. All collected saliva samples were promptly stored on ice, centrifuged, and then stored in a −80 degree freezer on the same day as collection.

For each of the two Condition sessions in Study 2, all participating mothers received intranasal OT or a placebo during separate visits to the research center. These visits were scheduled for the same time of day, approximately one week apart, in a balanced within-subjects design. On arrival at the lab during these sessions, a single dose of 24IU OT (40.32μg, Syntocinon) or placebo was administered through three actuations to each nostril (4IU, 6.72μg each). After administration, participants were then asked to rest for an interval of 35 to 45 minutes to allow for the pharmacokinetics of OT to cross the blood-brain barrier (Quintana et al., 2021), before taking part in the naturalistic interaction task. This time period aligns with previous studies that reported changes in social behavior and cognition after OT administration compared to placebo (De Cagna et al., 2019). To ensure double-blindness, both the active and placebo nasal sprays were dispensed by independent pharmacists using identical bottles, and the order of the codes representing OT and placebo for each participant was randomized into a computer-generated list. Consequently, half of the participants received OT during their

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Table 1. Participant demographic characteristics in studies 1 and 2

Category		Total Sample ($N = 62$) %	Probable PND cases ($N = 26$) %	Controls ($N = 36$) %
Marital status	Married	79.3	73.1	83.3
	Cohabiting	9.5	11.5	8.3
	Single	11.1	15.4	8.3
Sexual orientation	Heterosexual	88.9	88.5	91.7
	Bisexual	3.2	7.7	0.0
	Missing	7.9	3.8	8.3
Parent to other children	Yes	15.9	11.5	19.4
	No	84.1	88.5	80.5
Educational level	University	79.3	84.6	77.9
	College	1.6	0.0	2.8
	School	1.6	3.8	0.0
	Missing	17.5	11.5	19.5
Birth control use	Non-hormonal	85.7	84.6	86.1
	Hormonal	14.3	15.4	13.9
Menstruating at Baseline	No	96.8	96.2	97.2
	Yes	3.2	3.8	2.8
Menstruating at the time of Placebo administration	No	98.4	100.0	98.4
	Yes	1.6	0.0	1.6
Menstruating at the time of OT administration	No	98.4	100.0	98.4
	Yes	1.6	0.0	1.6
Breastfeeding	Exclusively	82.5	80.8	86.1
	In combination	17.4	19.2	13.9
	No	0.0	0.0	0.0
Self-report of recent formal diagnosis	Postnatal depression	12.7	30.8	0.0
	Postnatal anxiety	14.3	34.6	0.0
	Psychosis	0.0	0.0	0.0
	Post-traumatic stress disorder	1.6	3.8	0.0
	Borderline personality disorder	3.2	7.7	0.0
Mental health history	Depression	20.6	38.5	8.3
	Anxiety	12.7	23.1	5.6
	Psychosis	1.6	3.8	0.0
	Post-traumatic stress disorder	1.6	3.8	0.0
	Borderline personality disorder	3.2	7.7	0.0
Currently receiving mental health treatment	Talking therapy	11.1	26.9	0.0
	Antidepressant	3.2	3.8	2.8
	None	85.7	69.2	97.2
Previous mental health treatment	Talking therapy only	15.9	30.8	5.6
	Antidepressant only	1.6	0.0	2.8
	Talking therapy and antidepressant	6.3	11.5	2.8
	None	76.1	57.7	88.9
Pregnancy length	Full term	79.4	80.8	80.6
	Premature	12.7	15.4	11.1
	Missing	7.6	3.8	8.3

(*Continued*)

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Table 1. (*Continued*)

Category		Total Sample ($N = 62$) %	Probable PND cases ($N = 26$) %	Controls ($N = 36$) %
Birth delivery	Vaginal	68.2	73.1	63.9
	C-section	31.7	26.9	36.1
Birth delivery was induced	Yes	34.9	46.2	27.8
	No	57.1	53.8	61.1
	Missing	7.9	0.0	11.1
Epidural during delivery	Yes	54.0	53.8	55.6
	No	38.1	46.2	33.3
	Missing	7.9	0.0	11.1
Primary nationality	British	52.4	42.3	61.1
	Non-British	47.6	57.7	38.9
First language	English	71.4	73.1	72.2
	Other	28.6	26.9	27.8

first visit, while the other half received OT during their second visit to the research center.

Materials and methods

Mind-mindedness

During the 5-minute naturalistic interaction with their infant, each mother's speech was transcribed, and mind-related comments were coded using the Mind-mindedness Coding Manual (Meins & Fernyhough, 2015). These mind-related comments were coded into two dichotomous categories of "appropriate" or "non-attuned" mind-related comments based on the coder's independent interpretation of whether the mother's comment suitably mapped on to the infant's behavior during the interaction.

Inter-rater reliability (IRR) was evaluated using a randomly selected 25% of the sample. This was performed by two raters who were blind to both the participant's mood scores and condition (IRR outcomes: total number of mind-related comments: $\kappa = .93$; appropriate comments: $\kappa = .74$; non-attuned comments $\kappa = .75$). To account for differences in verbosity, mind-related comments were calculated as a proportion of the total number of utterances, and the proportional scores were used in subsequent analyses. There were some instances (12.9%, $n = 8$; including $n = 2$ probable PND cases and $n = 6$ controls) where the data could not be transcribed due to translation issues or because one mother did not make any utterances during the interaction, and this data was therefore missing.

Oxytocin (OT)

All infant saliva samples were promptly stored on ice after collection, and then centrifuged for 15 minutes at 3000rpf at 4°C. The samples were then divided into approximately 1 ml volumes and stored at −80°C on the same day as collection. These saliva samples were later transported to RIAgnosis, maintained at −80°C, where they were assayed for OT using a radioimmunoassay (RIA). On arrival at RIAgnosis, all samples were stored at −20°C. During the analysis, 300 µl of saliva was initially evaporated with a SpeedVac machine. Then, 50 µl of assay buffer was added to the extract and evaporated, respectively, to assay OT using a specific and sensitive radioimmunoassay (RIAgnosis). This protocol has been previously validated for use with both plasma and cerebrospinal fluid (Kagerbauer et al., 2013). Briefly, an antibody was added to each 50 µl sample. After a 1-hour preincubation period, a 10 µl of a 125I-labeled tracer was introduced to the sample, which was then incubated for 3 days at 4°C. Unbound radioactivity was precipitated using activated charcoal. In these environments, typically 50% of total counts are bound with less than 5% non-specific binding. The detection limit ranges between 0.1 and 0.5pg/sample, depending on the age of the tracer, with typical displacements of 20%–25% at 2pg, 60%–70% at 8pg, and 90% at 32pg of standard neuropeptide. Although all participants had been provided with identical instructions for infant saliva collection, not all of the infants produced a sufficient amount of saliva for analysis. We found 11.3% ($n = 7$; $n = 4$ probable PND cases, $n = 3$ controls) of the data was missing.

Results

Descriptive statistics and preliminary analyses

Kolmogorov–Smirnov and Shapiro–Wilk tests identified a mild skewness in the distribution of maternal EPDS scores (skewness = .88, $SE = .34$, kurtosis = .27, $SE = .67$). Therefore, Spearman's correlations were used for analyses involving EPDS scores. Table 2 illustrates the correlations between EPDS scores and critical demographic variables. As shown in Table 2, maternal EPDS scores were unrelated to all demographic variables, except for sexual orientation, in which bisexual orientation was positively associated with maternal EPDS scores, $r_s = .27$, $p = .039$. However, this was driven by two outliers from the clinical group. There was no significant group difference in sexual orientation between mothers who reported symptoms of PND above and below the clinical cutoff point on the EPDS. An independent samples *t*-test showed there was a significant group difference in maternal age between mothers who scored above the clinical cutoff point on

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Table 2. Correlation matrix for associations between maternal depression, mind-mindedness, and demographic variables in study 1

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. EPDS score													
2. Infant Age	.10												
3. Maternal Age	−.15	−.10											
4. Educational Level	−.04	.02	.06										
5. Sexual Orientation	.27*		−.16	−.04	.19								
6. Marital Status	.13	.18	−.27*	.01									
7. Mother to Other Children	−.08	−.07	.12	−.09	.16	−.03							
8. Nationality	.12	−.15	.29*	.06	−.12	−.09	.03						
9. Hormonal Birth Control Use	−.03	−.20	−.16	−.08	.18	.14	−.07	.08					
10. Menstruation at Baseline	.14	−.14	−.04	−.04	.48***	.18	.17	.12	.18				
11. Pregnancy Duration	−.07	−.14	−.01	.06	.08	−.24	.05	−.11	−.11	−.20			
12. Mode of Childbirth	.03	.16	−.16	.01	−.07	−.17	−.15	.01	.11	−.26*	−.08		
13. Infant Weight	.07	.40**	−.08	.11	−.02	.02	−.13	−.06	−.02	−.01	.05		
14. Appropriate mind-related comments	−.26	.06	.16	−.02	−.14	−.12	.15	−.08	−.23	.18	.09	−.01	
15. Non-attuned mind-related comments	.02	−.14	−.11	.27	−.06	−.06	.10	.03	−.05	−.05	.06	−.11	.15

*$p < .05$, **$p < .003$, ***$p < .001$

Table 3. Means and standard deviations of the mind-mindedness variables and infant salivary OT in studies 1 and 2

Condition	Variable	Probable PND Mean (SD)	Non-depressed Mean (SD)
Baseline	Appropriate mind-related comments	.02 (.03)	.03 (.03)
Baseline	Non-attuned mind-related comments	.02 (.02)	.02 (.02)
Baseline	Infant salivary OT	1.13 (.23)	1.28 (.32)
After OT administration	Appropriate mind-related comments	.03 (.03)	.06 (.05)
After OT administration	Non-attuned mind-related comments	.02 (.02)	.02 (.02)
After Placebo administration	Appropriate mind-related comments	.03 (.06)	.05 (.05)
After Placebo administration	Non-attuned mind-related comments	.02 (.02)	.02 (.02)

the EPDS (M age = 32.02) and mothers who scored below (M age = 34.89), $t(55) = 2.56$, $p = .013$.

The distribution of infant OT concentration was normal (skewness = .57, $SE = .34$, kurtosis = −.27, $SE = .67$). However, skewness was observed in both appropriate mind-related comments (skewness = 1.37, $SE = .34$, kurtosis = 1.53, $SE = .67$) and non-attuned mind-related comments (skewness = 2.48, $SE = .73$, kurtosis = 7.34, $SE = .67$). As shown in Table 2, these mind-mindedness indices were unrelated to all demographic variables. A significant outlier was identified in the non-attuned mind-related comments scale ($SD = 4.5$). This outlier was excluded from the subsequent analyses involving mind-mindedness, which adjusted the skewness to 1.21, $SE = .35$, and the kurtosis to 1.94, $SE = .70$.

The relation between maternal mind-mindedness and infant OT at baseline (study 1)

A Pearson correlation test was used to examine the relation between maternal mind-mindedness and infant OT at baseline (Study 1). A positive correlation was found between infant OT and appropriate mind-related comments, $r(43) = .34$, $p = .022$, implying that a higher number of appropriate mind-related comments is associated with a higher level of infant OT. There was no significant correlation found between infant OT and non-attuned mind-related comments, $r(43) = .09$, $p = .554$.

The relation between maternal mind-mindedness and maternal mood at baseline

There was a non-significant trend for an association between maternal EPDS scores and appropriate mind-related comments at baseline, $r_s(49) = -.26$, $p = .070$. However, there was no association between EPDS scores and non-attuned mind-related comments, $r_s(49) = .02$, $p = .872$. Table 3 displays the mean mind-mindedness scores for the groups of probable PND cases and controls. There was a trend suggesting that women in the non-depressed group scored higher on appropriate mind-related comments than those in the depressed group, $t(49) = -1.99$, $p = .052$, $d = .56$, representing a medium sized effect. In contrast, there was no significant difference between the groups with respect to non-attuned mind-related comments, $t(49) = -.40$, $p = .689$, $d = .11$. These results suggest a trend toward a specific relation between maternal mood and appropriate mind-related comments, although the results did not reach statistical significance in this sample.

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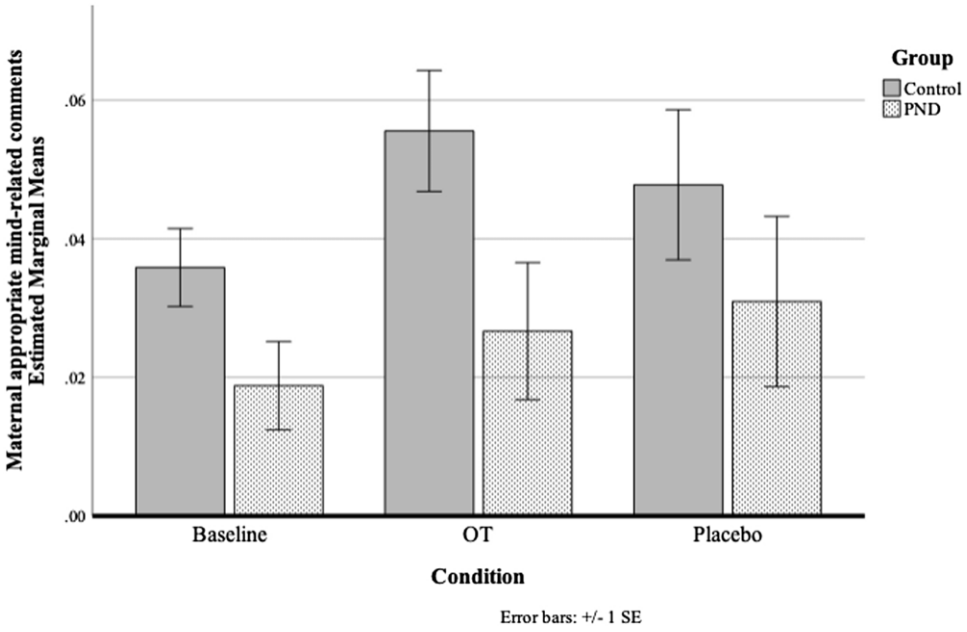

Figure 1. Appropriate mind-related comments by group and condition (study 2).

The relation between infant OT and maternal mood

In examining the relation between maternal EPDS scores and infant OT, a non-significant trend-level negative correlation was found, $r_s(53) = -.26$, $p = .054$. Table 3 displays the mean OT concentrations of infants of mothers in the probable PND and control groups. The difference in infant OT levels between these two groups was borderline significant, $t(53) = 1.94$, $p = .058$, $d = .53$, representing a medium effect size. These results suggest a trend toward a relation between maternal mood and infant OT, with lower OT levels found in the infants of mothers experiencing more severe depressive symptoms. However, the results did not reach the conventional level of statistical significance in this sample.

The effect of exogenous OT nasal administration on maternal mind-mindedness (study 2)

In Study 2, a three-way repeated measures ANOVA was carried out to study any changes in maternal mind-mindedness following the administration of intranasal OT, relative to a placebo. The ANOVA involved maternal mind-mindedness score at each of the three conditions (baseline, post-OT, and post-placebo) as within-subject variables, and participant group (PND and control) as the between-subjects variable. Mean mind-mindedness scores at the baseline, and post-OT, and post-placebo conditions are displayed in Table 3.

There was a significant group difference for appropriate mind-related comments between the women who reported symptoms of PND above the clinical cutoff and those below, $F(1, 46) = 5.07$, $p = .029$, partial eta-squared ($\eta_p 2$) = .01, indicating a small effect size. However, there was no significant effect of Condition, $F(2, 92) = 1.76$, $p = .181$, $\eta_p 2 = .04$, nor any significant interaction effect between Condition and Group, $F(2, 92) = .37$, $p = .671$, $\eta_p 2 = .01$. Mean scores and associated 95% confidence intervals can be seen in Figure 1.

For the non-attuned mind-related comments, no significant group difference was found between women with symptoms of PND above the clinical cutoff and those below, $F(1, 46) = .01$, $p = .94$, $\eta_p 2 < .001$. Moreover, there was no significant effect of Condition, $F(2, 92) = .88$, $p = .414$, $\eta_p 2 = .02$, nor any significant interaction effect between Condition and Group, $F(2, 92) = .13$, $p = .870$, $\eta_p 2 = .01$, on non-attuned mind-related comments. These results are represented graphically in Figure 2. These results suggest that nasal administration of OT did not significantly influence maternal mind-mindedness, as measured by the use of appropriate or non-attuned mind-related comments, in neither the PND nor control groups. However, the presence of PND symptoms was associated with differences in the use of appropriate mind-related comments.

Discussion

In this paper, we investigated the relation between maternal mind-mindedness, OT in mothers and infants, and symptoms of PND. Consistent with our predictions, in Study 1 we found a significant positive correlation between the use of appropriate mind-related comments by mothers and the concentration of OT in infant saliva. In addition, we observed a trend ($p = .052$) in which mothers experiencing symptoms of depression above the clinical threshold used fewer appropriate mind-related comments compared to controls.

These associations – between maternal mind-mindedness and symptoms of maternal depression, as well as between maternal mind-mindedness and infant OT – were specific to the use of appropriate mind-related comments by the mother. There were no associations with the use of non-attuned mind-related comments. The results from Study 1 therefore underscore the potential role of mothers' appropriate mind-related comments, specifically, in relating to children's early OT levels, and the effect of maternal depression and infant OT on understanding variation in mothers' mind-mindedness.

These results constitute the first evidence of a relationship between maternal mind-mindedness and children's hormonal variations. Considering that the infant's OT system is influenced by maternal caregiving during critical developmental periods and

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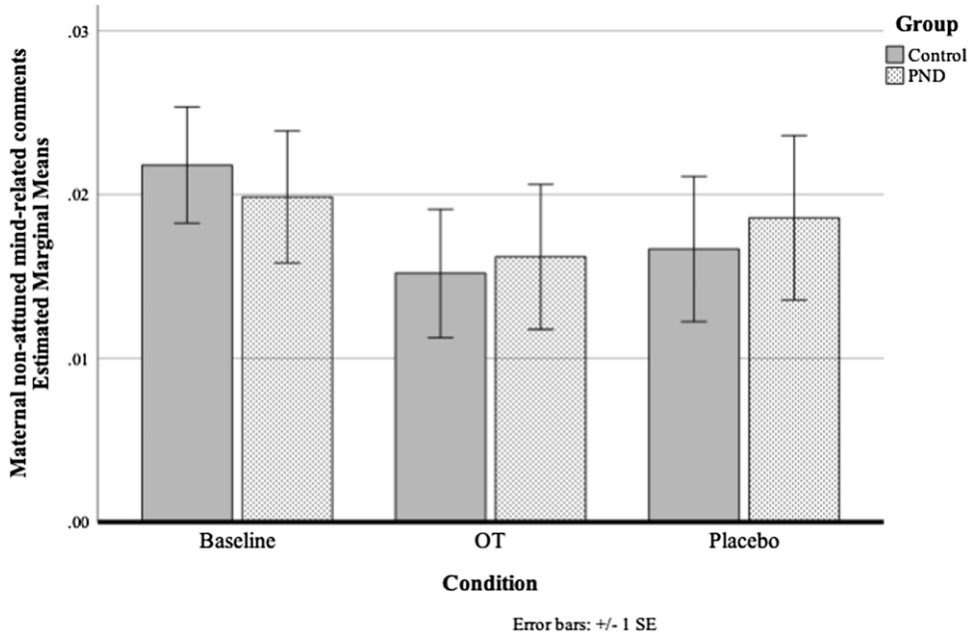

Figure 2. Non-attuned mind-related comments by group and condition (study 2).

shaped by epigenetic factors (Feldman, 2015, 2021; Perkeybile et al., 2019; Toepfer et al., 2017), we suggest that the degree of mind-mindedness a mother displays during interactions with her infant may relate to the child's social orientation via modulating their OT levels. In turn, higher levels of OT in infants may encourage social orientation and appropriate mind-related comments in mothers, since the enhancement of social orientation in the child is likely to intensify the mother's attention to and understanding of her infant's internal state. This interpretation is in line with the finding that only appropriate – and not non-attuned – mind-related comments correlated with infant OT levels.

Our findings therefore raise new questions for future research to explore; such as how maternal mind-mindedness and infant OT may mutually influence one another, and whether this relation could be bidirectional, as well as their potential implications for maternal and infant well-being. For example, our findings along with the separate longitudinal associations previously found related to both child OT and maternal mind-mindedness with favorable outcomes in children's social and emotional development (Apter-Levy et al, 2013; Bernier et al., 2017; Colonnesi et al., 2019; Laranjo & Bernier, 2013; Meins et al., 2019; Nikolic et al., 2022; Priel et al, 2019), may signal a new direction for research to investigate between these variables to deepen our understanding of the mechanisms leading to vulnerabilities in children's mental health development (Feldman, 2015, 2021; Larkin et al., 2021). Further research is needed to test these assumptions.

It is of note that we also found a trend ($p = .054$) in our sample indicating a negative correlation between infant OT and maternal depressive symptoms. A trend was further observed ($p = .058$) toward a group difference in infant OT concentration between the children of mothers who reported experiencing symptoms of PND above the clinical cutoff point on the EPDS and those who scored below. This aligns with past research that has reported lower OT levels in children of mothers with depression (Apter-Levy et al., 2013; Priel et al., 2019).

The question of how a mother's mental state attribution relates to her child's OT levels, and whether this relationship is mediated by her own emotional expressions, therefore also remains an important area for future research to explore. Considering that OT usually promotes parent–child engagement by interacting with the stress regulation system and reward neural pathways (Atzil et al., 2011) – both of which are affected in PND (Post & Leuner, 2019) – it is plausible that these also contribute to facilitating mind-mindedness.

In Study 2, we employed an experimental design to examine the effect of a single dose of exogenous OT administered nasally to mothers compared to a placebo on mind-mindedness. In this study, we observed no significant impact of either intranasal OT or placebo on the mind-mindedness of mothers, irrespective of their scores above or below the clinical cutoff for depression. This could reflect OT's person-dependent nature, as its therapeutic effect can be influenced by emotional context as well as interactions within the socio-cognitive and reward neural pathways, which are known to be disrupted in PND (Carter, 2022; Toepfer et al., 2017). For example, nasally administered OT has been found to change mothers' perception of urgency and choice of parenting strategy in response to infant cry sounds in mothers with diagnosed PND, but has no effect on their sensitive caregiving (Mah et al., 2017). Whether this applies to our sample is less clear, since we did not assess participants in this study using a clinical diagnosis of depression. However, other investigations that used the same screening measure of PND have further found effects of OT on maternal mood in mothers with mild symptoms of PND, and not in mothers with elevated symptoms of depression (Lindley Baron-Cohen et al., 2022). A further consideration is that the single dose of OT administered in this study might have been insufficient to elicit noticeable changes in mind-mindedness in either group. It is also possible that the effects of OT could have been amplified if administered alongside a psychological therapy (De Cagna et al., 2019). A final possibility is that maternal OT does not have a direct effect on maternal mind-mindedness. All of these considerations should be tested in future research.

This study demonstrates, however, that the double-blind experimental protocol with new mothers is both feasible and

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acceptable. Since our sample included a subgroup of women experiencing symptoms of PND who were breastfeeding their infants during the study, future studies could also explore whether breastfeeding moderates the associations between maternal mood, mind-mindedness, and infant and maternal OT. It is possible that breastfeeding could potentially have a protective effect, mitigating the impact of maternal low mood on maternal mind-mindedness and infant OT. However, further research is needed to test this hypothesis.

The current findings may additionally have several potential clinical applications. First, our findings are in line with previous studies showing difficulties in mind-mindedness among mothers with elevated symptoms of depression (Pawlby et al., 2010; Schacht et al., 2017). This suggests that targeting mind-mindedness in screening and treatment for PND could help mitigate present and future difficulties in parent–child relationships. Second, identifying which mothers with PND also face difficulties in their parent–child relationships can be complex in clinical settings, since existing screening measures often rely on parent self-report, which is vulnerable to underreporting due to social stigma (NCT, 2017). In addition, more reliable video-coding measures of parent–child interactions, while beneficial, are time-consuming for clinicians and pose implementation challenges (Zilcha-Mano et al., 2020). Therefore, child or maternal OT levels may potentially offer a feasible, alternative method as part of a screening measure of risk in the parent–child relationship for use in clinical services. This proposal would require more research, but is mentioned as a potential avenue to be considered.

Our findings underscore the necessity of addressing not only mothers' depressive symptoms but also any associated difficulties in the parent–child relationship in the year after childbirth. At present, first-line treatments for PND in the United Kingdom involve Cognitive Behavioral Therapy or SSRI antidepressant medication, either alone or combined (NICE Guidance, 2014). Similar approaches are prevalent in many other countries, where treatment primarily involves counselling or SSRI antidepressant medication (Yu et al., 2021). However, these interventions largely focus on the mother's depressive symptoms without directly addressing any associated difficulties in the parent–child relationship, which are unlikely to resolve without specific intervention (Bauer et al., 2014).

Promising evidence has emerged from studies that have explored the use of mentalization-based treatment (MBT) to enhance mentalizing abilities and improve the parent–child relationship in vulnerable new mothers (Byrne et al., 2019; Schuman et al., 2018). These studies have reported substantial improvements in maternal reflective capacity and sensitive caregiving behavior. In addition, trials involving broader samples for depression treatment have shown that combining MBT with psychodynamic psychotherapy significantly reduced moderate to severe depression (Fonagy et al., 2020). Future research could therefore evaluate the effectiveness of MBT, either alone or in combination with OT administration, in mothers with PND to address both maternal depressive symptoms and challenges in the parent–child relationship.

Interventions focusing specifically on facilitating mind-mindedness, either through video feedback or the use of smartphone applications, have also been shown to effectively improve mind-mindedness in new mothers, including those with severe mental health issues (Larkin et al., 2019; Schacht et al., 2017). To our knowledge, there have been no treatment trials focusing specifically on improving mentalizing or mind-mindedness for PND, or for women exhibiting significant depression scores in the absence of a formal diagnosis. Investigating this will be important since prior research has shown that infrequent use of appropriate mind-related comments, as found in our depressed sample, can predict the development of externalizing difficulties in children (Fishburn et al., 2022).

Given that maternal mind-mindedness during pregnancy predicts children's developmental outcomes (Steele et al., 2016), and maternal OT levels during pregnancy predict PND symptoms (Cevik & Alan, 2021), it may be beneficial to initiate mind-mindedness treatments during pregnancy in vulnerable new mothers. This would target the caregiving system during its activation and significant maternal brain reorganization, coinciding with the significant neurobiological interaction between mother and fetus (Slade et al., 2020). Further research could test this assumption.

The results of the current studies should be interpreted in the context of several limitations. First, PND cases were identified solely based on their EPDS scores. Although the EPDS has been validated as a reliable indicator of PND in previous studies (Martin & Redshaw, 2018), we did not perform any clinical diagnostic assessment, and therefore, we cannot comment on the severity of PND in this sample. In addition, since meta-analytic data indicate a stronger relation between depression and mind-mindedness in studies using self-report measures of mind-mindedness rather than observational measures (Georg et al., 2023), this could also be noted as a limitation of the present study. Second, while a power calculation determined that our sample size was adequately powered to detect case–control differences, the number of cases in the analyses examining maternal depression was relatively small ($n = 26$), and since there was also some missing data, our findings should be interpreted tentatively as a demonstration of principle until they have been replicated. This limitation, along with the inability of our study to detect medium-sized effects for the negative association between EPDS scores, mothers' appropriate mind-related comments, and infant OT, underscores the need to replicate our findings. Third, although the cross-sectional design used in Study 1 was able to test the present hypotheses, future research may benefit from using a longitudinal study design. Future studies should also consider collecting infant OT samples at multiple time points, and from plasma as well as saliva samples (Martins et al., 2020; Perkeybile et al., 2019).

In conclusion, Study 1 provides new evidence for a bio–behavioral link between maternal mind-mindedness and infant OT levels, illustrating one potential pathway through which maternal mind-mindedness may contribute to children's development. This relationship was found to be specific to mothers' use of appropriate mind-related comments. Study 1 also found a decrease in the usage of appropriate mind-related comments in women reporting elevated symptoms of PND. Study 2 provides preliminary evidence for the feasibility and acceptability of a randomized double-blind experimental protocol using nasal OT administration with new mothers who experience PND. These findings are of potential clinical significance, as they offer new insight for the assessment and treatment of risk factors in parent–child relationships and early child development. Additionally, they contribute to our understanding of the biological underpinnings and mediating factors that influence the impact of early mother–infant interactions on a child's development. Future studies are needed to further explore these relationships and their potential therapeutic implications.

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