Infant Temperament and Postpartum Depression

Influence of Infant Temperament on Treatment Outcomes Following Maternal Postpartum Depression Treatment

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Lay Abstract

In research, we have often looked at how mothers' postpartum depression (PPD) affects their infants, but far less research has examined how infants might affect mothers' and other PPD treatment outcomes. The objective of this thesis was to see if aspects of infants' temperament, their biologically based behavioral differences, influence infants' and mothers' responses to maternal PPD treatment. In the first study, we examined if an infant's distress when they face limitations affects how mothers responded to treatment. The second study assessed how infant fear affected whether or not they benefited from their mothers being treated. We found that mothers of infants with higher distress benefited less from therapy. Using heart rate and brain measures of infant emotion regulation, we observed that infants with more fear derived fewer benefits from maternal treatment. Understanding infant temperament can potentially help to improve outcomes for them and mothers who participate in PPD treatment.

Abstract

Objectives: To investigate the influence of infants' temperamental traits on outcomes for both infants and their birthing parents following postpartum depression (PPD) treatment

Methods: In Study 1, we analyzed data from a cohort of 40 birthing parents and their infants affected by PPD. We investigated whether the distress to limitation subdomain of infant temperament influences the mother-infant relationship and maternal response to group cognitive behavioural therapy (CBT) treatment for PPD. In Study 2, we examined the same 40 dyads with PPD and included a healthy control group. The control group was matched to the PPD group on infant age, sex, and socioeconomic status. Here, we explored the impact of infant fear on infant response to maternal CBT for PPD. To assess outcomes in preverbal infants, we employed physiological measurements including heart-rate variability (HRV) and frontal alpha asymmetry (FAA). In both studies, we measured infant temperament using maternal reports on the Infant Behavior Questionnaire–Revised Short Form.

Results: In Study 1, higher infant distress to limitation was associated with less improvement in depressive symptoms and a decline in infant bonding immediately and three months after group CBT. In Study 2, findings indicated a significant post-intervention increase in infant HRV, which persisted for three more months. Furthermore, negative correlations were identified between baseline infant fear and changes in HRV, suggesting that infants exhibiting higher levels of fear derived less benefit from maternal PPD treatment. Although FAA exhibited a leftward shift post-treatment for up to three months, no correlation was observed between baseline infant fear and changes in FAA.

Conclusions: The studies in this thesis suggest that infant temperamental factors can influence CBT treatment outcomes for both birthing parents and their infants.

Keywords: Infancy, Temperament, Postpartum depression, Cognitive behavioural therapy

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I find myself reflecting not only on the countless hours spent working on data, reading papers, or preparing for conferences but also on the invaluable experiences and connections that shaped my journey. I met many people, heard many stories, and learned many lessons. As I conclude this chapter of my life, I am grateful for all the lessons learned, the friendships forged, and the support of those who believed in me.

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List of Abbreviations

ANS: Autonomic Nervous System

CAD: Canadian Dollar

CBT: Cognitive Behavioural Therapy

d: Cohens d

DSM-5: The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition

ECG: Electrocardiography

EGG: Electroencephalography

EPDS: Edinburgh Postnatal Depression Scale

ER: Emotion Regulation

FAA: Frontal Alpha Asymmetry

fNIRS: Functional Near Infrared Spectroscopy

HRV: Heart Rate Variability

HF-HRV: High Frequency-Heart Rate Variability

IB: Impaired Bonding

IBQ-R SF: Infant Behaviour Questionnaire-Revised Short Form

MDD: Major Depressive Disorder

MINI: Mini International Neuropsychiatric Interview

PBQ: Postpartum Bonding Questionnaire

PFC: Prefrontal Cortex

PPD: Postpartum Depression

PSNS: Parasympathetic Nervous System

REDCAP: Research Electronic Data Capture

RCT: Randomized Controlled Trial

SD: Standard Deviation

Socioeconomic status: SES

SNS: Sympathetic Nervous System

TAU: Treatment as Usual

RSA: Respiratory sinus arrhythmia

β: unstandardized beta

Declaration of Academic Achievement

I drafted the initial versions of the manuscripts for both studies and collaborated with co-authors to finalize them for inclusion in this sandwich thesis. Below I describe my contributions and those of my coauthors.

Study 1: I conceptualized the study's objectives, conducted data analyses, and wrote the initial manuscript. Dr. Ryan Van Lieshout contributed to the study's conceptualization, provided guidance on data interpretation, and offered critical feedback on the final manuscript. Dr. John Krzeczkowski conducted data collection, study conceptualization, and supported data analysis and interpretation. Additionally, Dr. Louis Schmidt assisted with neurophysiological data collection.

Study 2: I conceptualized the objectives, conducted data analyses, and created the initial manuscript. Dr. Ryan Van Lieshout contributed to the study's conception, guided data interpretation, and provided critical feedback on the final manuscript. Dr. John Krzeczkowski conducted the data collection, contributed to the study's conceptualization, and provided support for data analysis and interpretation. Additionally, Dr. Louis Schmidt assisted with neurophysiological data collection

Chapter 1. Background

1.1. Postpartum Depression in Birthing Parents

Approximately 20% of birthing parents will develop postpartum depression (PPD) after the birth of an infant (Gaynes et al., 2005; Meaney, 2018). Even symptoms that do not meet the diagnostic criteria for major depressive disorder can adversely affect the mother-infant relationship and offspring outcomes (Moehler et al., 2006). The symptoms of PPD generally align with those of DSM-5 major depressive disorder (MDD), encompassing depressed mood, anhedonia, energy depletion, sleep and appetite disturbances, difficulty concentrating, irritability, and even suicidal thoughts (American Psychiatric Association, 2022). Based on the DSM-5 criteria, PPD requires the onset of a major depressive episode within 4 weeks following parturition, with persistence of symptoms for 12 months or more (Goodman, 2004; O'Hara, 2009; Wisner et al., 2002).

1.2. Postpartum Depression and Offspring

While PPD is widely recognized for its negative impact on birthing parents' well-being, it can also significantly influence the health and development of their infants (Stein et al., 2018). Extensive evidence suggests that children born to birthing parents with untreated PPD face an elevated risk of various adverse outcomes, like cognitive and behavioral problems during childhood (Goodman et al., 2011) and an increased likelihood of developing depression in adulthood (Netsi et al., 2018).

Emotion Regulation

Emotion regulation (ER), the process of appraising and modifying emotions in the pursuit of future goals (Thompson, 1994), can also be adversely affected by exposure to maternal PPD and may be a crucial mediator of sub-optimal outcomes in later life. Individuals with robust ER capacity can effectively abstain from impulsive or inappropriate behaviors, manage bodily arousal, and redirect attention amid intense positive or negative emotions (Thompson, 1994). However, infants as young as three months exposed to PPD demonstrate challenges in ER (Field et al., 1995).

Measurement of Emotion Regulation

Observational assessments of infant behaviour and measurements of neurophysiological activity have been employed to evaluate infant ER (Lusby et al., 2014; Porges, 2007; Thayer et al., 2009). Physiological measurements in particular have proven valuable as they can offer more objective insights into infants' behavioural processes, considering their preverbal nature.

Heart rate variability (HRV), which gauges the time variation between heartbeats, is one neurophysiological indicator of infant ER. It assesses the parasympathetic nervous system (PSNS) branch of the autonomic nervous system (ANS). While the sympathetic nervous system (SNS) branch of ANS readies the body to respond to stress, the PSNS fosters bodily relaxation. The vagus nerve, a key PSNS component, innervates the heart and governs the cardiovascular system, inhibiting the SNS's effect on the cardiac system (Thayer & Brosschot, 2005). In restful periods, the vagus nerve acts as a "brake," slowing the heart rate by enhancing vagal output to the sinoatrial (SA) node and restraining sympathetic influences. However, during stress, the vagal "brake" disengages, decreasing vagal output to the SA node and causing a heart rate increase (Graziano & Derefinko, 2013). High frequency variations in heartbeat, or high-frequency HRV (HF-HRV), can be used to quantify vagal tone. The HF-HRV is often associated with respiratory sinus arrhythmia (RSA), which refers to the natural variation in heart rate that occurs with breathing. During inhalation, the heart rate tends to increase, and during exhalation, it tends to decrease. In infants, HF-HRV frequency usually ranges from 0.24 to 1.04 Hz (Laborde et al., 2017), and increased HF-HRV at rest indicates enhanced ER by reflecting optimal PSNS activity in adapting to the environment (Propper & Moore, 2006).

Electroencephalography (EEG) can be used to assess infant corticolimbic brain activity by measuring resting frontal alpha asymmetry (FAA), the relative activity of the right and left frontal brain hemispheres. The primary index employed to evaluate FAA involves subtracting the total power in the brain’s alpha frequency band (8–12 Hz) recorded at the left frontal electrodes from the alpha power at the right frontal electrodes (Barros et al., 2022). Alpha activity inversely corresponds to cortical activity, where reduced alpha power signifies heightened cortical activity, and increased alpha power signifies diminished cortical activity (Bazanova & Vernon, 2014). A relatively more left frontal cortical activity compared to the right has been linked to approach motivation, positive affect, and improved ER (Zsigo et al., 2024). On the other hand, those exhibiting higher right FAA are believed to have a more dominant withdrawal motivation, potentially increasing their vulnerability to difficulties in ER and psychopathology (Harmon-Jones & Allen, 199).

2. Dyadic Interactions

The impact of PPD on birthing parents and infants is characterized by changes in crucial dyadic interactions. Tronick's mutual regulation model emphasizes the significance of early mother-infant interactions in establishing a dyadic regulatory system (Gianino & Tronick, 1988; Tronick & Beeghly, 2011). Infants employ vocal cues, facial expressions, and physical gestures to convey socioemotional and homeostatic needs to their caregivers. On the other hand, birthing parents contribute to regulation by recognizing and responding in a timely way to their infants' cues.

2.1.Birthing Parents in Dyadic Interactions

Maternal PPD can influence the mother-infant relationship and interactions (Barry et al., 2015; Brummelte & Galea, 2016). Those experiencing PPD tend to exhibit lower levels of empathy, sensitivity, and responsiveness to their infants' needs (Field, 2010), breastfeed less frequently (Dias & Figueiredo, 2015), and report challenges in connecting with their newborns (Coates et al., 2014). Moreover, individuals with PPD are more likely to display harsh parenting behaviors (Lovejoy et al., 2000), or show reduced positive engagement during face-to-face interactions with their infants (Field, 2010).

2.2. Infants in Dyadic Interactions

Classical theories of mother-infant relations, such as those proposed by Spitz and Bowlby, tended to adopt a "tabula rasa" perspective on the human infant—a philosophical concept depicting the infant mind as a "blank slate" at birth (Goldsmith & Campos, 1982). This perspective implies that individuals are primarily shaped by their experiences, offering limited consideration of how infants might actively participate in dyadic interactions. However, pioneers like Sameroff (1975) and Belsky (1984) were among the first to recognize that infants are not merely passive recipients of parental behavior; they can also influence their parents' emotions and actions. Sameroff emphasized the reciprocal interactions between children and their family environments, highlighting their interdependence (Sameroff & Mackenzie, 2003). An example of a transactional mother-infant dynamic is Patterson's coercive model (Patterson, 1982). This model outlines a process wherein harsh parenting initially influences children's oppositional behaviors. Subsequent attention or compliance from parents in response to the child's defiance unintentionally reinforces aversive behavior, escalating parental frustration and a return to harsh practices (Patterson, 2002).

Temperament, inherent variations in activity level, emotional responsiveness, and self-regulation, serves as a crucial mechanism for child-to-parent effects (Rothbart, 1981). Introduced in 1981, the Infant Behavior Questionnaire (IBQ) by Rothbart has become one of the most extensively utilized parent-report measures of infant temperament. Its reliability and validity have been substantiated through numerous investigations, such as those conducted by Clark et al., (1997) and Fagen et al., (1987). Revised versions of IBQ, such as IBQ –Revised Short Form (IBQ- R SF), have also proven valuable due to their brevity and putting less demand on parents to complete them (Putnam et al., 2014). These tools have been crucial in establishing temperament as a vital factor in parent-child interactions, influencing parenting practices, parental stress, and bonding (Oddi et al., 2013). The IBQ-R SF has three broad components: Negative Emotionality, Positive Affectivity/Surgency, and Orienting/Regulatory Capacity. In particular, negative emotionality has been implicated in mother-infant interactions within PPD literature (Nolvi et al., 2016; Roubinov et al., 2022; Takács et al., 2020). Negative emotionality corresponds to the personality trait of Neuroticism and is identified by strong positive associations with feelings (and IBQ-R SF subdomains) of Sadness (low mood), Distress to Limitations (distress in response to being restricted substantial negative or unable to perform a desired action), Fear (distress in response to novelty or strangers), along with associations with Falling Reactivity, the rate of recovery from arousal (Putnam et al., 2014).

Little research has explored transactional interactions in the context of PPD. Most studies on the impact of PPD on the mother-infant dyad have focused on how parental PPD affects offspring (O'Connor, 2002; Paschall & Mastergeorge, 2016). In the sparse research on the topic, studies on the impact of children on their parents mainly focused on older children and adolescents (Hughes & Gallone, 2010; Kouros & Garber, 2010). However, exploring child-to-parent effects requires a consideration of age. Studies, such as those by Yan and Dix (2014), have noted associations between maternal depression and internalizing symptoms in children aged 2-3 years, with such associations being primarily driven from parent to child in the years following early childhood.

While temperament is considered biologically based, with certain temperamental subdomains having strong genetic influences, environmental factors can be influential (Goldsmith et al., 1987; Goldsmith et al., 1999; Shiner et al., 2012; Zwir et al., 2018). As children mature, they engage with a broader array of social environments, including interactions with additional caregivers such as teachers in daycare or school (Roubinov et al., 2022). This has the potential to attenuate the almost exclusive influence exerted by parents on young infants that is observed in the early stages of development (Roubinov et al., 2022). Therefore, infancy, during which infants are still adapting to the world and have not encountered diverse environments, provides a special window to explore how inherent temperamental traits affect birthing parents, especially in the context of PPD. (Takács et al., 2020).

3. **Objectives of the Present Thesis**

In recent years, the treatment of PPD has garnered substantial attention, driven by a growing recognition of the adverse effects it has on both birthing parents and their infants, as well as the considerable strain it places on the healthcare system and society (Bauer et al., 2016; Gavin et al., 2005), with two-thirds of these costs being accounted for by the offspring (Bauer et al., 2016). Psychotherapy, including cognitive-behavioral therapy (CBT), is a first-line intervention for PPD, often favored by birthing parents over antidepressant medications (Goodman et al., 2009; MacQueen et al., 2016). While CBT treatment has yielded significant benefits for dyads (Cicchetti et al., 2000; Cohen et al., 2002; Stein et al., 2018; Van Doesum et al., 2008), it is crucial to consider factors that may influence the extent of these benefits for birthing parents and their offspring. A substantial body of literature has explored maternal factors, such as age, unmarried status, older age, and comorbid personality disorder, and their association with a poorer response to CBT (Ammerman et al., 2012; Driessen et al., 2010; Fournier et al., 2009; Haby et al., 2006; Hamilton & Dobson, 2002), yet no study, to our knowledge, has investigated infant factors that predict PPD treatment outcome.

This dissertation utilizes infants' biologically determined dispositional characteristics, as assessed through temperament, to evaluate outcomes of PPD treatment for both birthing parents and their offspring. Existing research on infant temperament and

PPD often concentrates on general temperament aspects, such as negative emotionality (e.g., Roubinov et al., 2022; Takács et al., 2020). While this approach enhances our comprehension of infant temperament in dyadic interactions, there is a crucial need to delve into specific temperament subdomains to uncover subtleties within mother-infant interactions, a focus that this dissertation addresses in the subsequent chapters.

Chapter 1: The Effect of Infant Distress to Limitation on Postpartum Depression Treatment Response and Mother-Infant Bonding

In the first study, we examined the associations between infant temperament, the mother-infant relationship, and maternal response to CBT for PPD. We specifically explored the distress to limitation subdomain of IBQ-R SF which assesses infants' discomfort and/or frustration due to being restricted or constrained when they wish to do an activity (Rothbart, 1981). Such limitations are frequent during infancy and often require attention or action from their birthing parents. This highlights the need for birthing parents to consistently attend to alleviate infant stress, making distress to limitation a significant component of parent-infant interactions and a salient aspect of temperament sensed by parents (Nolvi et al., 2016). The study results revealed that higher levels of infant distress to limitation were linked to less reduction in birthing parents' depressive symptoms and decreased infant bonding after group CBT, both immediately and three months post-treatment.

Chapter 2: Effects of Infant Fear on Changes in Infant Heart Rate Variability Physiological Outcomes After Maternal Postpartum Depression Treatment

In the second study, we investigated the impact of infant temperament on infants' response to maternal CBT for PPD. Specifically, we focused on fearfulness which is a stable and adaptable temperamental trait that emerges in early infancy (Adolphs, 2013). Fear can predict later social development; higher fear levels correlate with reduced sociability with strangers, social anxiety, and withdrawal during toddlerhood and beyond (Andersson et al., 1999; Calkins & Fox, 1992; Kagan, 1997; Kiel & Buss, 2014). We used objective physiological measurements of heart-rate variability (HRV) and frontal alpha asymmetry (FAA) to assess emotion regulatory outcomes in preverbal infants, both of which involve brain circuitry that implicates the rise and regulation of fear as an emotion (Graham et al., 2016; Wei et al.,2018). Results revealed a significant increase in infant HRV post-intervention, persisting three months later. Negative correlations were found between baseline infant fear and changes in HRV, indicating that fearful infants benefited less from CBT for PPD. While FAA became left-shifted post-treatment for up to three months, no correlation was observed between baseline infant fear and changes in FAA.

Overall, our findings suggest that infant temperamental factors can influence CBT treatment outcomes for both birthing parents and their infants, broadening the scope of predictive indicators in the treatment of PPD. The first study in this thesis is under review and the second study is in the process of being prepared for submission. Both studies of this thesis include data from the same study and as a result, there are some instances of duplication in the methods.

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Chapter 2

Study 1: The Effect of Infant Distress to Limitation on Postpartum Depression Treatment Response and Mother-Infant Bonding

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Context and Implications: This study sought to determine how temperament, infants' biological predisposition, impacts the outcomes of PPD treatment for birthing parents. We found that mothers of infants with high distress to limitation, a salient aspect of temperament, benefitted less from treatment. The key takeaway from our results is the importance of recognizing and understanding the impact of infant-to-birthing parent effects in predicting treatment response.

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Abstract

Background: Despite theoretical support for the transactional model of development, it is unclear how infant factors influence postpartum depression (PPD) treatment outcomes in birthing parents. This study sought to address this gap by examining associations between infant temperament, the mother-infant relationship, and maternal treatment response to group cognitive behavioral therapy (CBT) for PPD.

Methods: Forty birthing parents with major depressive disorder (MDD) in the first postpartum year with infants less than 12 months old participated in a nine-week group CBT intervention. Birthing parents provided information on infant distress to limitation (Infant Behavior Questionnaire-Revised Short-Form), depressive symptoms (Edinburgh Postnatal Depression Scale), and mother-infant bonding (Postpartum Bonding Questionnaire). Data were collected before treatment, immediately post-treatment, and three months later.

Results: Higher levels of infant distress to limitation were associated with less reduction in depressive symptoms and reduced infant bonding after group CBT for PPD both immediately after and three months post-treatment.

Limitations: Participants who were largely White, middle class, married, and who had access to Universal healthcare in Canada may limit study generalizability. The lack of a depressed control group also precludes causal conclusions.

Conclusions: The birthing parents of infants who had higher levels of distress to limitation benefited less from CBT treatment. These results highlight the importance of examining infant-to-birthing parent effects in the context of PPD as a predictor of

treatment response, which can eventually be used to further optimize interventions for the benefit of both birthing parents and their infants.

Introduction

Postpartum depression (PPD) affects up to 20% of birthing parents and can negatively impact them and their infants (Gavin et al., 2005; Gaynes et al., 2005; Lanes et al., 2011; Racine et al., 2021). Even symptoms that do not meet the diagnostic criteria for major depressive disorder can adversely affect the mother-infant relationship and offspring outcomes (Moehler et al., 2006). Postpartum depression is also associated with less optimal parenting practices (Slomian et al., 2019) and more cognitive, emotional, and behavioral problems in offspring (Grace et al., 2003; Liu et al., 2017). Psychotherapy, including cognitive-behavioral therapy (CBT), is a first-line treatment for PPD and is often favored over antidepressant medications (Goodman et al., 2009; MacQueen et al., 2016). Understanding the factors that influence PPD treatment response is crucial for optimizing outcomes for birthing parents and their infants.

Sameroff (1975) and Belsky (1984) were among the first to note that infants are not merely passive recipients of parental behavior but can influence their parents' emotions and actions as well. Indeed, Sameroff highlighted the interconnected and reciprocal interactions that occur between children and their family environment, emphasizing that neither function completely independently (Sameroff & Mackenzie, 2003). Infant temperament is one important mechanism by which child-to-parent effects can occur (Thomas et al., 1963). Temperament, inherent variations in infant activity level, emotional responsiveness, and self-regulation that are biologically based (Goldsmith et al., 1987; Shiner et al., 2012), can play a role in parent-child interactions and can influence parenting practices, parental stress, and bonding (Belsky, 1984; Oddi et al., 2013).

Most research examining how PPD affects the mother-infant dyad has focused on the effects of parental PPD on offspring (O'Connor, 2002; Paschall & Mastergeorge, 2016). Those who have examined the effects children have on their parents have primarily involved older children and adolescents (Hughes & Gallone, 2010; Kouros & Garber, 2010). However, age is crucially important to studies examining child-to-parent effects. Studies have observed links between maternal depression and internalizing symptoms in children aged 2-3 years, but these associations tend to be primarily from parent to child in the years after early childhood (e.g., Yan & Dix, 2014). As children grow older and engage with different social environments (e.g., daycare, school) and caregivers (e.g., teachers), the strong connection between maternal mood symptoms and children's outcomes can weaken (Roubinov et al., 2022). Thus, the first year after birth, when infants are still new to the world and have not interacted extensively with their environment, provides a unique opportunity for exploring how infants' inherent temperamental characteristics influence birthing parents, especially in the context of PPD (Takács et al., 2020).

A small but important literature exists that has examined associations between infant temperament, maternal depression and mother-infant bonding. For instance, Curci et al. (2022) showed that behavioral problems in one-year-old infants predicted higher levels of maternal depressive symptoms at 1.5 years. Moreover, 18 months old infants' negative emotionality has been shown to predict later maternal depressive symptoms

(Roubinov et al., 2022), as well as poorer mother-infant bonding (Nolvi et al., 2016; Takács et al., 2020). Studies have also suggested that irritable behavior in infants can contribute to the development and persistence of depression in birthing parents, and that infant irritability present prior to the development of parental depression significantly increases the likelihood of later PPD (Cutrona et al., 1986; Murray et al., 1996). However, very little is known about how infant dispositional characteristics affect birthing parent response to PPD treatment.

It is important to note that most research on infant temperament and PPD focuses on broader temperament aspects, like negative emotionality (e.g., Roubinov et al., 2022; Takács et al., 2020). While this perspective enhances our understanding of infant temperament within dyadic interactions, there is a need to delve into specific temperament domains to identify nuances within mother-infant interactions. Specifically, the distress to limitation subdomain of temperament, which gauges infants' discomfort or frustration stemming from restrictions on desired activities deemed unsafe or inappropriate by parents (Rothbart, 1981), holds particular promise as an influence on maternal PPD. Infant frustration or fussiness, which are typical behavioral expressions of distress when infant activities are restricted, necessitate consistent attention from birthing parents to alleviate infant stress (Nolvi et al., 2016). Consistently managing infants prone to frustration or frequent crying could worsen and perpetuate PPD symptoms in birthing parents (Radesky et al., 2013; Yim et al., 2015) and could interfere with maternal response to PPD treatment. Elevated levels of infant distress to limitation in particular have also been linked to poor mother-infant bonding in those with PPD (Nolvi et al., 2016).

Treating PPD is crucial to parental well-being (Sockol, 2015), and may lead to improvements in the mother-child relationship, and infant emotional and behavioral functioning (e.g., Amani et al., 2023; Amani et al., 2021; Cicchetti et al., 2000; Cohen et al., 2003; Horowitz et al., 2001; Merza et al, 2023; Milgrom et al., 2015; Murray & Cooper, 2003; Ntow et al., 2021; Krzeczkowski et al., 2021; Van Doesum et al., 2008; Van Lieshout et al., 2021; Van Lieshout et al., 2020). However, to our knowledge, no study has explored how infant temperament, particularly distress to limitation, impacts the effectiveness of PPD treatment in birthing parents and mother-infant bonding.

The purpose of this study was to examine associations between infant temperament, the mother-infant relationship, and maternal treatment response to group cognitive behavioral therapy (CBT) for PPD. Assessing temperament in the context of PPD treatment could reveal dyads at risk for poor treatment response and enable us to optimize interventions to benefit both birthing parents and their offspring.

Methods

Participants:

The present study sample was comprised of 40 birthing parents with a diagnosis of major depressive disorder (MDD) within the first year after giving birth, along with their infants. These individuals were patients of the Women's Health Concerns Clinic, a specialty perinatal mental health clinic located at St. Joseph's Healthcare Hamilton in

Ontario, Canada. Individuals with MDD and attending the clinic were given the option to receive a 9-week group CBT for PPD intervention. During the first CBT session, women were extended an invitation to join the current study. Participants were recruited between March 2016 and July 2019.

To be eligible for the study, participants had to have a primary diagnosis of MDD in the postpartum period. Psychiatric diagnoses were made by mental health clinicians using a semi-structured interview format according to DSM-5 criteria and were confirmed by a psychiatrist. Individuals who had co-morbid psychiatric conditions (so long as they were not bipolar disorder, schizophrenia spectrum disorder, and/or a substance use disorder) were eligible for participation. Individuals who were not fluent in English or whose infants were older than 12 months were also not eligible to participate. Fourteen participants (35%) received a diagnosis of MDD before childbirth, while twenty-six (65%) were diagnosed during the postpartum period.

Intervention and Study Design:

The nine-week group CBT for PPD intervention was delivered weekly by psychotherapists in pairs (Van Lieshout et al., 2017), and each session lasted two hours. During the first half of each session, core CBT content was covered, while the second half involved discussions on relevant topics that were co-led by both patients and therapists.

Data were gathered at three time points. Visit 1 (T1), occurred after the first CBT session. Visit 2 (T2) took place immediately after treatment completion and visit 3 (T3) occurred three months after the CBT group had concluded. The study received approval from the Hamilton Integrated Research Ethics Board (Study Number 0912), and all participants provided their informed consent before participating.

Measures

Infant Temperament:

Infant temperament was assessed using the Infant Behavior Questionnaire-Revised Short-Form (IBQ-R SF) and was completed by birthing parents. It contains 91 questions rated on a 7-point scale (1-7) (Putnam et al., 2014). While previous studies examining infant temperament and PPD primarily focused on broader aspects of temperament like negative emotionality (e.g., Takács et al., 2020), we specifically explored the distress to limitation subdomain which assesses infants' discomfort and/or frustration due to being restricted or constrained when they wish to do an activity (Rothbart, 1981). Given that such limitations are frequent during infancy, experiencing distress in response to being restricted is a salient aspect of temperament. This highlights the need for birthing parents to consistently attend to alleviate infant stress, making distress to limitation a significant component of parent-infant interactions (Nolvi et al., 2016), and thus a valuable marker of how infant temperament influences maternal treatment outcomes. The distress to limitation subscale (7 questions) had an acceptable Cronbach's α of 0.68 (Ursachi et al., 2015). Higher scores were indicative of more distress to limitation in the infant.

PPD in Birthing Parents:

The EPDS is a gold-standard measure of PPD symptoms and consists of 10 self-reported items that assess depressive symptoms experienced in the previous week (Cox et al., 1987). Each question is rated over the past seven days and scored from 0 to 3 with total scale scores, ranging from 0 to 30 points. In our study, EPDS had a very good Cronbach α of 0.85 with higher scores suggestive of higher levels of PPD symptoms (Cox et al., 1987).

Mother-Infant Bonding:

Birthing parents also completed the Postpartum Bonding Questionnaire (PBQ), which contains 25 items each of which is scored on a 6-point scale (0–5) (Brockington et al., 2001). The PBQ assesses the quality of the mother-infant bond after childbirth, detects potential problems within the relationship, and contains four subscales. This study focused on the impaired bonding subscale given its high sensitivity and ability to reflect bonding quality between birthing parents and their offspring (Brockington et al., 2001). The impaired bonding subscale (Cronbach's α=0.69) has 12 questions and higher impaired bonding scores indicate poorer bonding.

Statistical Analyses:

Descriptive statistics (mean, standard deviation, percentage) summarizing study participant characteristics data were summarized for continuous variables and frequencies for dichotomous variables. We used paired t-tests to investigate how EPDS and PBQ scores changed following CBT treatment, both immediately (T1-T2) and 3 months post-treatment (T1-T3). We then used linear regression models (i.e., bivariate regressions) to investigate associations between baseline (T1) infant distress to limitation, PPD (continuous EPDS scores at T2 and T3), and mother-infant bonding (continuous PBQ impaired bonding scores at T2 and T3). Statistically significant results were defined as $p<.05$ (two-tailed). Statistical analyses were performed using the sjstats package (v0.18.2; Lüdecke 2022) and rstatix package (v0.7.2; Kassambara 2023) in RStudio.

Results

The characteristics of the sample are summarized in Table 1. We obtained data from a total of 40 birthing parents with PPD and their infants at T1, 40 dyads at T2, and 33 dyads at T3. At T1 the average age of birthing parents was 32.3 (4.1) years, and infants were 5.6 (2.7) months, all infants were carried to term. Most were White and had a high school education or greater. Their mean before-tax household income was on average $80,000/year (Canadian dollars) and 92.1% were married or living common-law.

Sixteen participants (40%) were diagnosed with a co-morbid psychiatric condition, specifically generalized anxiety disorder. Sixty-three percent completed all nine CBT sessions, six (15%) completed eight sessions, five (13%) completed seven sessions, and four (10%) completed six sessions. The average household income, education, and marital status did not show any correlation with the number of CBT sessions attended. No individual participated in additional psychosocial treatments throughout the 9-week group CBT course.

Mean values for IBQ-R SF distress to limitation, EPDS and PBQ impaired bonding scales are reported in Table 2. Paired samples t-tests indicated a statistically significant decrease in EPDS scores (decrease in depressive symptoms) immediately after treatment (T1 to T2, p <0.01), which persisted to three months post-treatment (T1 to T3, p <0.01). The PBQ values for impaired bonding did not change immediately after CBT (T1 to T2, p =0.21), but were significantly decreased (i.e., bonding improved) when comparing changes from T1 and T3 (p =0.04).

Greater levels of infant distress to limitations at baseline (T1) were associated with increased scores of maternal depression immediately after CBT (T2), indicating a potential connection between infant distress and birthing parents' depressive symptoms (Correlation coefficient (R) = 0.38, p = 0.02). Similarly, greater levels of distress to limitations at baseline (T1) were associated with higher PBQ scores (poorer bonding) immediately after treatment (T2) (R = 0.46, p < 0.01). Three months after CBT treatment (T3), the positive correlation between baseline infant distress to limitations and EPDS scores persisted (R = 0.49, p < 0.01), and impaired bonding remained associated with higher levels of infant distress to limitations (R = 0.42, p = 0.02). Baseline infant distress to limitation correlated with baseline bonding scores (R = 0.39, p = 0.03), but not baseline EPDS scores (R = 0.25, p = 0.14).

Table 1. Characteristics of Study Participants

Infant age in months, m (SD)	
Visit 1	5.6 (2.7)
Visit 2	7.7 (2.7)
Infant sex, no (%) male	16 (40)
Birthing parents' age in years, m (SD)	32.3 (4.1)
Ethnicity, (%white)	97.5
Mean household income, CAD (SD)	80,000 (32,694)
Parity, no (%)	
Primiparous	21 (53)
Multiparous	19 (47)
Marital status, no (%)	
Single	3 (8)
Separated	1 (2)
Common-law	9 (22)
Married	26 (68)
Years of Education, m (SD)	16.4 (2.26)
Birthweight m (SD), grams	3329.5 (448.4)
Gestational age m (SD), weeks	39.5 (2.2)

Abbreviation: CAD, Canadian Dollars

Table 2. Infant temperament, Depression and Mother-infant Bonding Scores

Outcomes	**Visit 1, M (SD)**	**Visit 2, M (SD)**	**Visit 3, M (SD)**
IBQ-R SF Distress to Limitations	4.2 (1.1)	4.2 (1.2)	4.1 (1.1)
EPDS	14.5 (5.5)	11.0 (5.5)*	9.4 (6.2)*
PBQ Impaired bonding	23.7 (6.9)	21.9 (3.9)	20.7 (3.8)*

Abbreviations: EPDS, Edinburgh Postnatal Depression Scale; IBQ-R SF, Infant Behavior Questionnaire-Revised Short Form; PBQ, Postpartum Bonding Questionnaire. * denotes statistically significant difference ($p<0.05$) compared to Visit 1.

Discussion

While birthing parents' levels of depressive symptoms significantly decreased following group CBT for PPD treatment, more distress to limitations in their infants was associated with smaller improvements in depressive symptoms and poorer infant bonding both immediately post-treatment and three months later. To our knowledge, this is the first study to explore how infant temperament (i.e., infants' biologically based dispositional characteristics) affects treatment outcomes for those receiving PPD treatment.

Our results suggest that the birthing parents of infants who show higher levels of distress when they are exposed to limitations, improve less in response to treatment with CBT. Infant temperament at baseline did not correlate with maternal baseline depression scores, further supporting the inherent nature of distress to limitation in influencing birthing parent outcomes (Goldsmith et al., 1999). While Cutrona and Troutman (1986) and Roubinov et al. (2022) have established links between infant negativity and more maternal depressive symptoms, this study extends findings by suggesting that infant temperament is a factor that may influence PPD treatment outcomes, broadening the scope of predictive indicators in the treatment of PPD (Ammerman et al., 2012; Driessen et al., 2010; Fournier et al., 2009; Haby et al., 2006; Hamilton & Dobson, 2002).

While it is unclear exactly how infant distress to limitation predicted less change in PPD symptom levels in this study, several mechanisms could be involved. If the infant consistently expresses distress when faced with limitations, it is crucial for the parent to promptly address the infant's needs to avert the escalation of distress. This constant need for attentiveness in response to the baby's distress can lead to increased feelings of burnout and overwhelm for parents, particularly if they are experiencing PPD, and especially if partners or support systems are not readily available (Cutrona & Troutman; 1986; Dennis & Ross, 2006; Eberhard-Gran et al., 2002). This may have affected PPD symptoms on their own and/or reduced birthing parents' ability to participate in CBT sessions, hindering their learning and making it challenging to apply what they learned beyond sessions while engaging with their difficult infants. Moreover, a temperamentally difficult infant can lead birthing parents to question their self-efficacy in multiple realms (e.g., parenting abilities). The frustration of trying various approaches to calm difficult infants without success can lead to feelings of inadequacy, exacerbating maternal depression (Fox & Gelfand, 1994; Porter & Hsu, 2003). This can affect not only how birthing parents handle their infants but also their overall confidence in managing any stressful situation (Sanders & Woolley, 2005; Sevigny & Loutzenhiser, 2010). Indeed, parents of infants with more negative temperament tend to report lower levels of general and parenting self-efficacy (Cutrona & Troutman, 1986; Gross et al., 1994; Jones & Prinz, 2005).

Moreover, at all points, the birthing parents of infants with higher baseline distress to limitation reported poorer bonding with their infants. While to our knowledge, no study has examined how infant temperament predicts bonding after PPD treatment, this is consistent with previous observational research reporting associations between difficult infant temperament and worse mother-infant bonding (Takács et al., 2020; Edhborg et al., 2005; Parfitt et al., 2014). Indeed, our findings are consistent with those of Nolvi and colleagues (2016) who showed elevated levels of distress to limitation predict poorer mother-infant bonding. This study expands on previous findings, revealing that birthing parents of distressed infants report diminished bonding despite receiving PPD treatment. This may be attributed to the increased difficulty in forming a strong bond when infants consistently react negatively to activities perceived as limiting by them. However, it is important to mention that the link between bonding and temperament could have been bidirectional pre- and post-treatment. The PBQ, which measures bonding, reveals birthing parents' emotions and perceptions of their infants' behaviors. Thus, infant behavior and temperament are integral aspects reflected in the PBQ scores, providing an alternative explanation for the consistent correlation between bonding and temperament at all measurement points.

This study contains limitations that require acknowledgment. It relied solely on birthing parent reports of infant temperament, PPD and the mother-infant relationship. While self-reports of psychiatric symptoms are widely accepted in both research and clinical contexts (Nolvi et al., 2016), and parent reports have shown expected correlations with corresponding laboratory measures (Goldsmith & Rothbart, 1991; Kochanska et al., 1997; Rothbart & Goldsmith, 1985), such reports may contain biases. Furthermore, the participants in this study were primarily White, middle-class, and married, living in Canada with access to universal healthcare. All participants were individuals diagnosed with MDD, indicating that they were specifically those seeking and receiving treatment in a tertiary care center. As a result, the results of this work may not be generalizable to all birthing parents with PPD. Moreover, our study employed an observational design without a depressed control group, hindering our ability to establish causality between the variables under investigation. As a result, the observed changes might be attributed to CBT or other elements, including the passage of time or the medication effects as our sample did include individuals on antidepressants. Nevertheless, this study contributes novel evidence regarding infant temperament's role in influencing PPD treatment outcomes among birthing parents and establishes a foundation for future research with more robust study designs (including randomized control trials). While no studies to date have directly compared the effectiveness of psychotherapy for birthing parents alone to mother-infant psychotherapies, such work in the future could help us better understand how to optimize outcomes for both birthing parents and their offspring. To improve treatments, integrating temperament measurements into clinical assessments of mother-infant bonding may be an important potential first step.

Conclusion

This study reports associations between infant distress to limitation, birthing parent depressive symptoms, and mother-infant bonding in the context of PPD treatment, such that birthing parents of infants who had higher levels of distress to limitation benefited less from treatment. These results highlight the importance of examining and potentially addressing transactional mother-infant dynamics and infant-to-birthing parent effects in the context of PPD treatment to further optimize future interventions and maximize the benefits of treatment for both members of the dyad.

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Chapter 3

Study 2: Effects of Infant Fear on Changes in Infant Heart Rate Variability After Maternal Postpartum Depression Treatment

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Context and Implications: This study sought to determine how temperament, infants' biological predisposition, impacts the outcomes of PPD treatment for infants themselves. We found that while infants' emotion regulatory capacity improves after maternal PPD treatment, highly fearful infants benefit less from maternal treatment. The main takeaway from our results is the importance of addressing infant factors in the optimization of current or development of future interventions for PPD.

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Abstract

Background: While postpartum depression (PPD) is associated with adverse outcomes for infants, treating PPD can benefit mother-infant dyads. However, it is unclear if certain aspects of infant temperament, such as greater fear, can affect infants' ability to benefit from maternal PPD treatment.

Methods: Forty infants of birthing parents with major depressive disorder in the first postpartum year were matched 1:1 with 40 healthy control infants on age, sex, and family socioeconomic status. Birthing parents with PPD completed a nine-week group cognitive-behavioral therapy (CBT) intervention. Data were gathered at baseline (T1), post-treatment (T2), and three months later (T3). Infant emotion regulation was assessed using high-frequency heart-rate variability (HRV) and frontal alpha asymmetry (FAA) at every visit. Mothers also reported on their infant's temperamental fear using the Infant Behavior Questionnaire-Revised Short-Form.

Results: A statistically significant increase in HRV was noted immediately post-intervention ($p = 0.01$) in the infants of birthing parents with PPD, a finding that persisted three months post-treatment. However, negative correlations were observed between baseline infant fear and change in HRV from T1 to T2 (R=-0.37, $p = 0.02$) and from T1 to T3 (R =-0.46, p=0.02) in these infants. While FAA became left-shifted at T2 (p=0.01) and T3 ($p < 0.05$), baseline infant fear did not correlate with changes in FAA scores at T2 (R = 0.05 p =0.76) or T3 (R=0.01, p=0.93). No association was found between fear and changes in HRV or FAA in the control group.

Conclusions: Greater temperamental fear in infants is associated with improvement in HRV after maternal PPD treatment. These findings emphasize the need to study infant factors affecting the impact of maternal PPD treatment on them, which could enhance the benefits of maternal interventions for both parents and infants.

Introduction

Postpartum depression (PPD) affects up to 20% of birthing parents and can negatively impact them and their infants (Gavin et al., 2005; Gaynes et al., 2005; Lanes et al., 2011; Letourneau et al., 2017; Racine et al., 2021). Postpartum depression is associated with less optimal parenting practices (Slomian et al., 2019) and more cognitive, emotional, and behavioral problems in offspring (Grace et al., 2003; Liu et al., 2017). Indeed, up to two-thirds of the costs associated with PPD are due to its effects on infants and children (Bauer et al., 2016).

Evidence-based psychotherapies like cognitive-behavioral therapy (CBT) are first-line treatments for PPD and are often favored by many birthing parents over antidepressant medications (Goodman et al., 2009; MacQueen et al., 2016). While CBT is an effective treatment for PPD in birthing parents, much less attention has been paid to infant outcomes following maternal treatment, with studies yielding inconsistent results (e.g., Cicchetti et al., 2000; Cohen et al., 2002; Ammerman et al., 2015; Cooper et al., 2003). The majority of extant studies have relied solely on maternal reports of infant outcomes which may not fully capture the subtle yet important changes that occur in preverbal infants after maternal PPD treatment. Moreover, the few studies that have examined the impact of PPD treatment on offspring have not considered factors that reflect infant sensitivity to environmental changes. Identifying traits in infants that reduce their ability to benefit from maternal treatment could further enhance interventions and help identify those requiring additional support.

Decades of evidence have shown that temperamental fear in infancy remains stable throughout development and predicts socioemotional and behavioral outcomes for as long as 30 years (Fox & Henderson, 1999; Tang et al., 2019). Van Hulle et al. (2017) observed that infant fearfulness at six months of age predicted greater anxiety at eight years, while Chronis-Tuscano and colleagues (2009) found that infant fear as early as 14 months predicted the development of social anxiety disorder in adolescence. Tang and colleagues (2019) followed 14-month-old infants for 30 years and found that those who were identified as fearful became introverted adults who experienced more challenges in social and mental health domains. Fearful infants also demonstrate unique patterns of interaction with their parents (Kochanska et al., 2007; Volling & Feagans, 1995), and infant fear has been shown to adversely affect mother-infant bonding and increase parental stress (Nolvi et al., 2016; Roubinov et al., 2022; Takács et al., 2020).

Fear interacts within the emotion regulatory circuitry of the brain, including the autonomic nervous system (ANS) and frontal brain regions. Firstly, fear activates the sympathetic nervous system (SNS) branch of ANS, triggering the "fight or flight" response that readies the body for action. The parasympathetic nervous system (PSNS) counterbalances the SNS, promoting relaxation once the fear-inducing stimuli have subsided (Sevenster et al., 2015). Heart rate variability (HRV), which indicates the fluctuation in heart rate due to the interplay between SNS and PSNS activities, reflects emotion regulatory capacity (Field & Diego, 2008). In particular, high-frequency HRV (HF-HRV) indexes the PSNS activity, with higher HF-HRV suggesting better emotion regulation and adaptability to environmental changes (Sevenster et al., 2015). The HF-

HRV has been shown to be reduced in infants of birthing parents with depression (Gentzler et al., 2013; Amani et al., 2023), while also reflecting states of fear and startle (Sevenster et al., 2015; Wu et al., 2019). Secondly, frontal brain regions are crucial for higher executive functioning and modulation of responses during fearful situations (Graham et al., 2016). Frontal alpha asymmetry (FAA), which provides information on frontal brain activity, has been shown to be affected in infants of depressed mothers, with higher right FAA at rest linked to poorer emotion regulation (Goldstein et al., 2016; Jones et al., 1997; Jones et al., 1998). FAA can also reflect individual differences in fear processing (Liu & Zhou, 2020).

Considering the developmental stability of temperamental fear, its role in emotion regulation, and its impact on mother-infant dynamics, our study investigates how infant fear affects changes in infant emotion regulation after maternal PPD treatment. Assessing temperamental fear in the context of PPD could help identify infants who may be at risk for suboptimal outcomes following maternal treatment for PPD and enable the optimization of interventions for the benefit of birthing parents and offspring.

Methods

Participants:

The study was comprised of 80 infants and their birthing parents recruited from Hamilton, Ontario, Canada, and nearby municipalities between March 2016 and July 2019. Participants were divided into two groups: case dyads and control dyads. The case group was comprised of 40 birthing parents with major depressive disorder (MDD) diagnosed within the first year of delivery, along with their infants. These birthing parents were patients of the Women's Health Concerns Clinic, a specialty perinatal mental health clinic located at St. Joseph's Healthcare Hamilton in Ontario, Canada. Individuals with MDD and attending the clinic were given the option to receive a 9-week group CBT for PPD intervention. During the first CBT session, participants were invited to participate in the current study. To be eligible, birthing parents required a primary diagnosis of MDD, but not bipolar disorder, a schizophrenia spectrum disorder, and/or a substance use disorder. Psychiatric diagnoses (DSM-5) were made by mental health clinicians (e.g., nurses, social workers) using a semi-structured interview format and were confirmed by a psychiatrist. Individuals who had co-morbid psychiatric conditions were eligible. Additionally, those with other physical health problems were eligible, though none were present in the sample. Individuals who were not fluent in English or whose infants were older than 12 months were also not eligible to participate. Fourteen participants (35%) received a diagnosis of MDD before childbirth, while twenty-six (65%) were diagnosed during the postpartum period.

Control infants (n = 40), born to birthing parents without PPD, were matched 1:1 with case infants on age, sex, and familial socioeconomic status (SES; total household income [Canadian Dollars {CAD}]). This group was recruited to attempt to reduce the likelihood that any observed changes or associations following maternal treatment in case infants were due to developmental factors (occurring with age), sex, or other early adverse experiences. Birthing parents in the healthy control group did not receive any intervention. These control dyads were recruited from the Infant Database of the

Department of Psychology at McMaster University, which recruited from a similar catchment area to case dyads. Birthing parents who were not fluent in English, screened positive on the major depressive episode (current) module of the Mini International Neuropsychiatric Interview (Lecrubier et al., 1997), were taking psychotropic medications, and/or had infants older than 12 months were excluded. Participants were not excluded due to the presence of other physical health problems, although none were present in our sample.

PPD Intervention (Case dyads):

Birthing parents in the case dyad group received a nine-week group CBT for PPD intervention (Van Lieshout et al., 2017) delivered weekly by a pair of psychotherapists. Each session lasted two hours, the first half of which covered core CBT content, while the second half involved discussions on relevant topics co-led by both patients and therapists. We used the Edinburgh Postnatal Depression Scale (EPDS) to assess birthing parents' improvement in depressive symptoms following the intervention. The EPDS is a gold-standard measure of PPD symptoms which consists of 10 self-reported items that assess depressive symptoms experienced in the previous week (Cox et al., 1987).

Study design:

Data were gathered at three time points. For case dyads, Visit 1 (T1), occurred after the first CBT session, Visit 2 (T2) took place immediately after treatment completion and Visit 3 (T3) occurred three months after the CBT group had concluded. Control dyads had data collected during a baseline session (T1), 9 weeks later (T2), and three months after that (T3). All assessments were conducted at the Child Emotion

Laboratory at McMaster University. The study received approval from the Hamilton Integrated Research Ethics Board (Study Number 0912), and all participants provided their informed consent before participating.

Measures

Infant Temperament:

Infant temperament was assessed using the Infant Behavior Questionnaire-Revised Short-Form (IBQ-R SF) and was completed by birthing parents. It contains 91 questions rated on a 7-point scale (1-7) (Putnam et al., 2014). The fear subscale of IBQ-R SF measures the infant's reaction of startle or distress to sudden changes in stimulation, novel physical objects, or social stimuli (Putnam et al., 2014). The fear subscale (6 questions) had a Cronbach's α of 0.87 (Ursachi et al., 2015), with higher scores indicating greater temperamental fear in the infant.

Heart-rate Variability:

Two infant electrocardiogram (ECG) electrodes were positioned on the infants' backs, and data were wirelessly collected through Biolab software (v 3.2.3; Mindware Ltd.). Mindware HRV software (v 3.3.2) was employed to examine data for artifacts and analyze it in the frequency domain. Power within the infant high-frequency band (0.24–1.04Hz; Laborde et al., 2017) was recorded. In the case group, HRV data were unanalyzable for 1 infant at T1 and 7 at T3. In the control group, 2 infants at T1, 3 at T2, and 14 at T3 had unanalyzable HRV data due to excessive noise.

Electroencephalography:

Electroencephalography (EEG) data were recorded using Netstation (v.4.4.1) with 128-electrode HydroCel sensor nets at a sampling rate of 250Hz and referenced to the vertex (EGI Inc). The offline analysis was performed in EEGlab. Data were re-referenced to the average and then segmented into two-second epochs with a 50% overlap. Each epoch underwent a 100% Hanning window, and a Fourier transform was utilized to extract power within the "infant" alpha (α) band (6–9Hz; Bell, 2002). Frontal alpha asymmetry was computed by subtracting the natural log-transformed alpha power at the left frontal hemisphere (at site F3 [channel 24]) from the right frontal hemisphere (at F4 [channel 124]) [i.e., FAA = ln(F4) - ln(F3)]. In the case group, EEG data were unanalyzable for 6 infants at T1, 5 at T2, and 5 at T3. In the control group, 5 infants at T1, 6 at T2, and 7 at T3 had unanalyzable EEG data due to excessive noise.

Testing Procedure:

During study visits, standard infant protocols (Lusby et al., 2014) were followed to collect four minutes of resting-state physiological data. Infants were positioned on the birthing parents' laps facing forward, and a research assistant, seated at the infant's eye level, interacted with a toy placed 50cm in front of the infant's face. Birthing parents were given instructions not to communicate with their infants during this period.

Statistical Analyses:

Descriptive statistics (mean, standard deviation, percentage) summarizing study participant characteristics data were summarized for continuous variables and frequencies for dichotomous variables. Differences between case and control groups were assessed using $\chi 2$ and independent samples t-tests to investigate whether the groups differed from each other on demographic characteristics. We used paired t-tests to investigate how HRV and FAA measures changed following CBT treatment, both immediately (T1-T2) and 3 months post-treatment (T1-T3) in both dyadic groups. We used linear regression models (i.e., bivariate regressions) to investigate associations between baseline (T1) infant fear, change in HRV (difference in HRV scores for T1-T2 and T1-T3), and change in FAA (difference in FAA scores for T1-T2 and T1-T3). By definition infant temperament is inherently biologically based, with specific temperamental domains, including infant fear, displaying robust genetic influences (Goldsmith et al., 1999; Shiner et al., 2012; Zwir et al., 2018). To investigate fear's inherent nature in infants, we used linear regression to assess whether baseline maternal depression correlated with baseline infant fearfulness. We also used analysis of variance (ANOVA) to track changes in the measurement of infant fear between visits and groups. Statistically significant results were defined as $p<.05$ (two-tailed), and all statistical analyses were performed using the sjstats package (v0.18.2; Lüdecke 2022) and rstatix package (v0.7.2; Kassambara 2023) in RStudio.

Results

The characteristics of the sample are summarized in Table 1. We obtained data from a total of 40 birthing parents with PPD and their infants at T1, 40 dyads at T2, and 33 dyads at T3. We also obtained data from 40 healthy control dyads at T1, 40 dyads at T2, and 31 dyads at T3.

For the case group, the average age of birthing parents was (mean [SD]) 32.3 (4.1) years at T1, and infants were 5.6 (2.7) months. Their mean before-tax household income was on average $80,000/year (Canadian dollars), and 92.1% were married or living common-law. The control dyads did not show statistically significantly different demographic characteristics compared to case groups.

In the case group, sixteen participants (40%) were diagnosed with a co-morbid psychiatric condition, most commonly generalized anxiety disorder. Fifty-five percent (22 individuals) of case birthing parents were taking anti-depressants. Two had a medication change, and six had a dosage increase during the 9-week CBT treatment. Sixty-three percent completed all nine CBT sessions, six (15%) completed eight sessions, five (13%) completed seven sessions, and four (10%) completed six sessions. Household income, education, or marital status were not correlated with the number of CBT sessions attended. No individual participated in any other psychosocial treatments during the 9-week group. Paired samples t-tests indicated a statistically significant decrease in EPDS scores (i.e., a decrease in depressive symptoms) immediately after treatment (T1 to T2 ΔEPDS=-3.5 points, p <0.01, Cohen's d=0.65), which persisted to three months post-treatment (T1 to T3, ΔEPDS=-5.1 points, p <0.01, Cohen's d=0.88).

Mean values for IBQ-R SF fear, HRV, and FAA are reported in Table 2. Paired samples t-tests indicated a statistically significant increase in HRV scores of case infants immediately after treatment (T1 to T2, p=0.01, Cohen's d= 0.56), which improved to the levels of healthy control infants. This increase in HRV persisted three months post-treatment (T1 to T3, p <0.01, Cohen's d= 0.95).

We also observed a statistically significant shift from right to left FAA in case infants after treatment (T1 to T2, p=0.01, Cohen's d= 0.61), which was comparable to levels of healthy control infants. The FAA remained left-shifted three months post-treatment in case infants, statistically significantly changed from T1 (T1 to T3, $p < 0.05$, Cohen's d= 0.51).

An ANOVA revealed no significant main effect of group (case versus control) ($F(1, 215) = 0.50$, p=0.48), visit ($F(2, 215) = 1.22$, $p = 0.30$), or the interaction between group and visit ($F(2, 215)$=0.62, $p = 0.54$) on infant fear. There was also no statistically significant correlation between baseline infant fear and baseline maternal depressive symptoms (R=0.08, p=0.65).

We measured changes in values of HRV (ΔHRV) at T2 ([HRV at T1] subtracted from [HRV at T2]) and T3 ([HRV at T1] subtracted from [HRV at T3]). In case infants, greater levels of fear at baseline (T1) were associated with less increase in HRV scores (smaller ΔHRV) immediately after their mothers completed the group CBT intervention (Correlation coefficient (R)= -0.37, $p = 0.03$). Three months after CBT treatment (T3), the negative correlation between baseline infant fear and ΔHRV scores persisted (R = -0.46, p=0.02). Baseline fear did not correlate with ΔHRV scores among control infants at T2 (R = -0.04, p =0.82) or T3 (R = -0.16, p =0.52).

Changes in values of FAA (ΔFAA) at T2 ([FAA at T1] subtracted from [FAA at T2]) and at T3 ([FAA at T1] subtracted from [FAA at T3]) were also assessed. Infant fear at baseline was not correlated with the amount of ΔFAA from T1 to T2 (R = 0.05 p =0.76), and T1 to T3 (R = -0.08, p =0.71) in case infants. Moreover, baseline fear did not correlate with ΔFAA scores of healthy control infants at T2 (R = 0.04, p =0.87) and T3 (R = 0.01, p =0.93).

Table 1. Sample Characteristics for Case and Control dyads

	Case Dyads	**Control Dyads**
Infant age in months, m (SD)		
Visit 1	5.6 (2.7)	6.1 (2.6)
Visit 2	7.7 (2.7)	8.3 (2.7)
Infant sex, no (%) male	16 (40)	16 (40)
Birthing parents' age in years, m (SD)	32.3 (4.1)	32.8 (5.1)
Mean household income, CAD (SD)	80,000 (32,694)	84,012 (32,696)
EPDS score, m (SD)		
Visit 1	14.5 (5.46)	5.2 (4.2) *
Visit 2	11.0 (5.5)	4.3 (3.4) *
Visit 3	9.4 (6.2)	5.2 (4.2) *
Parity, no (%)		
Primiparous	21 (53)	21 (55)
Multiparous	19 (47)	17 (45)
Marital status, no (%)		
Single	3 (8)	1 (3)
Separated	1 (2)	0 (0)
Common-law	9 (22)	8 (21)
Married	26 (68)	29 (76)
Years of Education, m (SD)	16.4 (2.3)	17.4 (2.7)
Birthweight m (SD), grams	3329.5 (448.4)	3393.5 (478.1)
Gestational age m (SD), weeks	39.5 (2.2)	39.2 (1.1)

Abbreviation: CAD, Canadian Dollars. *denotes a statistically significant difference (p<0.05) compared to the case group.

Table 2. Infant Fear, HRV and FAA Scores at T1, T2, and T3

	Case Infants			**Control Infants**		
Outcomes	**Visit 1, M(SD)**	**Visit 2, M(SD)**	**Visit 3, M(SD)**	**Visit 1, M(SD)**	**Visit 2, M(SD)**	**Visit 3, M(SD)**
IBQ-R SF Fear	3.02 (1.55)	2.97 (1.24)	3.17 (1.17)	2.65 (1.25)	3.02 (1.14)	3.16 (1.15)**
Heart-rate variability	3.20 (0.88)	3.67 (0.78) *	4.16 (1.17)**	3.78 (0.81)	3.79 (0.93)	4.96 (1.42)
Frontal alpha asymmetry	-0.09 (0.31)	0.19 (0.58) *	0.09 (0.39) *	0.14 (0.36)	0.05 (0.31)	0.08 (0.30)

Abbreviations: IBQ-R SF, Infant Behavior Questionnaire-Revised Short Form; PBQ. * denotes statistically significant difference (*p*<0.05) compared to Visit 1 within each group. ** denotes statistically significant difference (*p*<0.001) compared to Visit 1 within each group.

Discussion

In this study, infants of birthing parents with PPD who received treatment showed an increase in HRV and a shift from right to left FAA, suggestive of improved emotion regulatory capacity. However, infant temperamental fear was associated with smaller improvements in infant HRV scores both immediately post-treatment and three months later. To our knowledge, this is the first study to explore how infant temperament (i.e., infants' biologically based dispositional characteristics (Shiner et al., 2012)) affects infant physiological emotion regulatory outcomes following maternal receipt of PPD treatment.

Consistent with Amani et al. (2023), we found that HRV scores increased following maternal receipt of PPD treatment. We provide additional context to these findings by showing that the HRV improvement with maternal treatment was less pronounced in more fearful infants. No such association was seen over a similar time interval in healthy infants, suggesting that the effects observed in case infants may have been due to maternal treatment and not developmental factors such as increasing age. Moreover, infant fear was not correlated with maternal depression at baseline, exhibited stability over time, and showed no statistically significant differences between the two groups, supporting its stable and inherent nature.

Several mechanisms could explain why fear influenced infant HRV change following birthing parent PPD treatment. Sameroff (1975) and Belsky (1984) were among the first to note that infants are not merely passive recipients of parental behavior but can influence their parents' emotions and actions via their temperamental attributes. In fact, infant fear, measured as part of infant negativity, has been shown to negatively impact the parent-child relationship and contribute to maternal depressive symptoms, poorer mother-infant bonding, and parental stress (Nolvi et al., 2016; Roubinov et al., 2022; Takács et al., 2020). Given the challenge of engaging fearful infants, birthing parents may inadvertently spend less time engaging with their infants for fear of inducing further distress, reducing their ability to benefit from improvements in maternal mood.

Biological roots of fearfulness may also contribute to the observed infant effects. First, prenatal development involves crucial epigenetic processes that can influence gene expression and development. It is plausible that infants with a genetic/epigenetic predisposition towards fearfulness may have experienced alterations in their epigenome during the prenatal (and early postnatal) period (Garfinkel et al., 2015; Guintivano et al., 2014), potentially constraining their capacity for emotion regulatory improvement following maternal receipt of PPD treatment. Moreover, infants born to birthing parents with higher prenatal maternal depressive symptoms show greater functional connectivity of the amygdala with prefrontal cortices (Qiu et al., 2015), with such connectivity being associated with higher fear at 6 months of age (Graham et al., 2016). Increased connectivity heightens infants' emotional reactivity, which could affect the ability of HRV, as part of the ANS, to engage with the prefrontal-amygdala circuit to produce optimal emotional reactions. Future research, employing imaging technology like functional near-infrared spectroscopy (fNIRS) is needed to examine the prefrontal cortex's activity in relation to the amygdala and the ANS, elucidating the circuitry responsible for heightened emotional reactivity in fearful infants.

Consistent with Amani et al. (2023), infants showed a left-shifted FAA after maternal PPD treatment suggestive of improved emotion regulation. However, baseline fear did not correlate with FAA improvement. The frontal cortex, investigated via FAA, relies on coordinated brain activity from multiple regions (Thayer & Lane, 2000), with top-down modulation of subcortical layers being limited during the early stages of life (Gao et al., 2015; Price et al., 2006). Thus, the association between the FAA and regulation of fear might take longer to become evident (Tottenham, 2020). This contrasts with brain systems underlying HRV which rapidly develop starting in the third trimester to help infants regulate bodily functions (Porges & Furman, 2011). Moreover, our small sample size might have prevented us from establishing an association. Additionally, collecting FAA while infants were at rest might have introduced variance for each subject (Coan et al., 2006; Stewart et al., 2014). Further investigation into task-related FAA, which better eliminates subject variance, with larger sample sizes can provide additional insights into infants' fear responses.

This study also contains limitations that require acknowledgment. The birthing parents in this study were primarily White, middle-class, and married, living in Canada with access to universal healthcare. The case dyads consisted of birthing parents diagnosed with MDD and treated in a specialty mental health clinic, and so had syndrome-level MDD and were treatment-seeking. As a result, the results of this work may not be generalizable to all birthing parents with PPD. Moreover, our study employed an observational design, hindering our ability to establish causality between the investigated variables. As a result, the observed changes could be due to CBT or other elements, including the passage of time or be contributed to by medication effects as our sample did include individuals taking antidepressants. Nevertheless, this study contributes novel evidence regarding infant fear's role in influencing infant outcomes following maternal PPD treatment and establishes a foundation for future research with more robust study designs (including randomized control trials). Future research should also employ high spatial resolution methods, such as fNIRS imaging, to investigate connectivity and its correlation with the regulation of fear in relation to parameters like HRV and FAA. Since increased fearfulness can have adaptive and maladaptive aspects, depending on the accompanying cognitive function (Graham et al., 2016), longitudinal studies should explore how emotion regulation and connectivity change in adaptive versus maladaptive fear. Lastly, while no studies to date have examined the impact of specific elements of psychotherapy on infant emotion regulation and/or directly compared the effectiveness of psychotherapy for birthing parents alone to mother-infant psychotherapies, such work in the future could help us better understand how to optimize outcomes for offspring in addition to birthing parents.

Conclusion

We found that infant fear, a stable trait throughout development, can influence infants' response to birthing parent PPD treatment. While infants may manifest physiological improvement from their parent's participation in CBT, fearful infants may benefit less. Our results highlight the importance of addressing infant characteristics in the context of PPD treatment to ensure the optimal outcome for the benefit of both birthing parents and their infants.

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Chapter 4: Discussion

4.1. Summary

This thesis aimed to assess how infant temperament influences treatment outcomes for birthing parents with PPD and their offspring. In the first study, we found that birthing parents of infants experiencing higher distress when faced with limitations showed smaller improvements in depressive symptoms following group CBT for PPD. We also found a consistent correlation between infant distress to limitation and maternal-infant bonding, underscoring the potential impact of infant temperament on the parent-child relationship. In the second study, while infants of birthing parents receiving PPD treatment showed adaptive changes in HRV and FAA following maternal PPD treatment, infant fear correlated with less improvement in HRV. The studies in this thesis contribute to the existing literature by highlighting how infant temperament can impact PPD treatment outcomes for both members of the mother-infant dyad.

4.2. Thesis Findings and the Transactional Model

The transactional model of development describes the interconnected and reciprocal interactions that occur between both members of the mother-infant dyad, emphasizing that neither functions completely independently (Sameroff and Mackenzie, 2003). In other words, the contributions infants make to the mother-infant dynamic not only influence their birthing parents but also have a significant impact on the infants themselves. With this perspective, infants with challenging temperamental traits may prompt specific responses from their parents during interactions. These responses could potentially exacerbate maternal PPD, ultimately affecting the infants themselves.

Infants with certain temperamental features, such as heightened distress to limitations or higher levels of fear, may require more attention from parents, which contribute to parental feelings of burnout and overwhelm (Cutrona & Troutman; 1986; Dennis & Ross, 2006; Eberhard-Gran et al., 2002). Moreover, the frustration of trying various approaches to calm difficult infants without success could lead to feelings of inadequacy, (Fox & Gelfand, 1994; Porter & Hsu, 2003), not only affecting how birthing parents handle their infants but also their confidence managing any stressful situation (Sanders & Woolley, 2005; Sevigny & Loutzenhiser, 2010). Parenting self-efficacy, and even general self-efficacy, have been consistently shown to be negatively influenced by temperamentally difficult infants (Cutrona and Troutman, 1986; Gross et al., 1994; Jones and Prinz, 2005). Lastly, engaging infants with high negative emotionality may lower parents' participation in CBT sessions, limiting their learning of skills to improve depressive symptoms. Diminished learning makes it difficult to apply CBT lessons at home, reducing the benefits for infants.

4.3. Caregiver Adversities and The Amygdala-Prefrontal Cortex Circuitry

While behavioral dynamics between birthing parents and infants may offer directly observable explanations, less easily observed factors may contribute to infants being inherently and differentially responsive to birthing parents after treatment. Infants' early experiences can shape their developmental trajectories in ways that make it harder for them to benefit from changes in their caregivers' mental health after treatment. Caregiving adversity, such as PPD, can act as a powerful stressor for the central nervous system, especially during the vulnerable infancy stage (Tottenham, 2020). In particular, the amygdala-prefrontal cortex (PFC) circuit, crucial for emotion regulation, has been consistently shown to be affected by caregiving (Qui et al., 2015; Rifkin-Graboi et al., 2015; Thijssen et al., 2017). The PFC tonically inhibits sympatho-excitatory subcortical circuits, including the amygdala, through GABAergic projections (Amat et al., 2005; Thayer, 2006). In uncertain or threatening situations, the PFC becomes hypoactive, disinhibiting circuits and setting the groundwork for an adaptive fight-or-flight response (Thayer, 2000; Thayer, 2006).

For optimal development, these systems require a protracted or slow development, allowing newborns repeated and gradual learning opportunities to acquire complex behaviors from their environment (Bjorklund, 1997). However, early caregiving adversities can accelerate the development of emotional regulation circuitry. Infants born to birthing parents with elevated prenatal maternal depressive symptoms demonstrate greater functional connectivity between the amygdala and ventromedial PFC (Qui et al., 2015). Moreover, while infants with engaged or sensitive parents have smaller amygdala volumes (Rifkin-Graboi et al., 2015) and reduced attentional avoidance in response to threats (Thrasher et al., 2021), those with lower parental sensitivity have accelerated the development of functional connections (Thijssen et al., 2017). Extensive research in animals has also established that adverse caregiving prematurely activates the amygdala (Debiec & Sullivan), promotes earlier myelination of amygdala cells (Guadagno et al., 2018), and amplifies amygdala excitability (Cohen et al., 2013).

Boyce and Ellis (2005) propose that increased physiological reactivity and faster development can help individuals adapt to environments that improve their fitness prospects from early in life. When caregivers are consistently present and engaged with their newborns, it would be inefficient to mature the amygdala systems, which are meant to support independent exploration of the environment (Tottenham, 2020). However, when caregiving is compromised (e.g. by PPD), these infants have a better chance of survival if they become more vigilant to environmental threats and risks (Boyce & Ellis, 2005; Tottenham, 2020).

Accelerated and earlier development of these circuits can heighten infants' emotional reactivity (Graham et al., 2016), possibly diminishing their ability for physiological improvement following maternal PPD treatment. Additionally, it can make them challenging to care for and contribute to maternal PPD. Conversely, the plasticity that initially makes the brain susceptible to adverse experiences can also act as its saving grace, allowing it to change in response to positive environmental changes. While our findings suggest that highly distressed infants facilitate a poor treatment response in both them and their birthing parents for up to three months post-treatment, it is possible that their brains may need more time to adapt to the modified caregiving environment. This might require assessing dyadic outcomes beyond the three-month follow-up point in our study. Ultimately, our results underscore the importance of considering infant factors in tailoring treatment approaches to ensure maximal benefits for all struggling with PPD.

4.4. Post-hoc Investigations

Mediational analyses

The connection between infant negativity and maternal depressive symptoms has been shown to be influenced by mother-infant bonding (Chang et al., 2023). Maternal

PPD is linked to increased emotional mismatches and decreased repairs in mother-infant interactions. Infants come to perceive these mismatches as challenging to rectify, reinforcing negative affectivity in them (Tronick & Reck, 2009).

To address this, *post-hoc* mediational analyses were conducted in Study 1 to compare the magnitude of the indirect effect of mother-infant bonding relative to the direct effect of infant temperament on maternal depressive symptoms measured via EPDS scores.

We found no significant mediation effect of bonding on the association between baseline distress to limitation and EPDS scores immediately after treatment and three months later. Milgrom et al. (2004) also found that maternal responsiveness is not a mediator between PPD at four months and child temperament at 42 months. It is important to note that responsiveness and mother-infant bonding are distinct constructs, but both provide insights into the quality of maternal interactions with infants. That said, the relationship between PPD and temperament is complex, possibly involving multiple variables that do not follow a simple path. For instance, past research has considered factors like maternal intrusiveness (Hummel & Kiel, 2015) and nutritional status (Avan et al., 2010) as potential mediators in the connection between PPD and child temperament. Lastly, our small sample size may have limited our ability to establish a mediating effect.

Moderation analyses

Considering the potential impact of temperamental influences on treatment outcomes through mother-infant behavioral dynamics (see section 3.2), particularly when infants challenge their birthing parents in caregiving, we sought to explore whether factors linked to maternal care could impact the strength of associations between infant temperament and dyadic treatment outcomes.

Firstly, we looked at parity. The family system reorganizes after the birth of a second child, and this shift is expected to create differences in relationships and interactions within single-child and multiple-child family systems (Stewart, 1990). Multiparous mothers seem to handle challenging infants with greater efficiency and effectiveness compared to primiparous mothers (Boukydis and Burgess, 1982). Fish and Stifter (1993) found that parity influences maternal attitudes and behaviors, with multiparous mothers reporting higher self-efficacy. Maternal parity even affects the neural response to infant affective cues (Maupin et al., 2017).

Secondly, partner support is crucial in helping birthing parents care for their challenging infant (Black, 2022). Research shows that support from partners is linked to positive parenting outcomes in young mothers (Contreras, 2004). Moreover, Easterbrooks et al., (2016) found that maternal depression was more likely to improve when mothers were content with the support they received from partners, while Edwards et al., (2012) showed that partner support is associated with lower levels of maternal postpartum depressive symptoms. Although we did not directly measure mothers' perception of partner support, we used our data on marital status to see if having a partner makes a difference.

To explore the impact of parity and marital status on the strength of associations between infant temperament and dyad treatment outcomes, we employed moderation analysis. In Study 1, we included a multiplicative parity*maternal EPDS (at both T2 and

T3) and parity*mother-infant bonding (at both T2 and T3) interaction score in our regression model. In Study 2, we introduced a multiplicative parity*ΔHRV (change at both T2 and T3) and parity*ΔFAA (change at both T2 and T3) interaction score into our regression model. A similar approach was applied to the marital status variable.

For all outcomes, the interaction term was not statistically significant. While parity may indicate previous parenting experience, it does not account for variations in the quality of that experience. A first-time birthing parent who receives adequate support and education may exhibit positive interactions comparable to those with higher parity. Similarly, while marital status indicates the presence of partner support, it does not reflect the quality of the support from the partner, as marital conflict has been consistently linked to poor outcomes for mothers with PPD (Odinka et al., 2018) and their children (Hanington et al., 2011; Krishnakumar and Buehler, 2000). Alternatively, our sample size might have been too small to observe interaction effects. Future research with larger sample sizes (and more statistical power) and assessments that measure partner support quality (such as Spanier’s (1976) Dyadic Adjustment Scale) and parenting practices (such as Clark’s (1999) Parent-Child Early Relational Assessment) should be conducted to explore these associations more fully.

4.5. Future Directions

Future studies should further explore how infant temperament influences outcomes of PPD treatment and understand the underlying mechanisms affecting both infants and birthing parents. Researchers can use longer follow-up durations with more robust study designs like randomized controlled trials (RCTs), to establish causal links.

Additionally, future studies could benefit from more direct and high-resolution methods for assessing nervous system activity. For instance, hyperscanning with functional near-infrared spectroscopy (fNIRS) provides a more detailed understanding of how specific brain areas associated with and influenced by infant temperament, affect treatment outcomes and the interactions between mothers and infants.

4.6. Conclusion

While treating PPD can benefit mother-infant dyads, the influence of infant characteristics on dyads' treatment outcomes has been poorly understood. The work presented in this thesis highlights the adverse influence of difficult infant temperament on PPD treatment outcomes for both infants and their birthing parents. Our results highlight the need to consider infant factors, like infant temperament, in developing future or optimizing current interventions for the benefit of both members of the dyad.

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