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The mother-infant relationship and infant development in the context of maternal childbirth-related posttraumatic stress symptoms

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THE MOTHER-INFANT RELATIONSHIP AND INFANT DEVELOPMENT IN THE CONTEXT OF MATERNAL CHILDBIRTH-RELATED POSTTRAUMATIC STRESS SYMPTOMS

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Abstract

The aim of this thesis project was to examine the associations between maternal childbirth-related posttraumatic stress symptoms (CB-PTSS) and mother-infant relationships and infant development at six months postpartum. CB-PTSS consists of two factors: birth-related symptoms (BRS, i.e., re-experiencing and avoidance symptoms) and general symptoms (GS, i.e., negative cognition and mood and hyperarousal symptoms). Mother-infant relationships in this thesis include: bonding, interactions, and synchrony (physiological and behavioral). In Study 1, the main focus was on investigating the associations between maternal CB-PTSS and mother-infant bonding, with infant development examined as a secondary outcome. Study 2 addressed differences in mother-infant interactions within the context of CB-PTSS. Study 3 primarily aimed to explore physiological synchrony between mothers and infants in the context of CB-PTSS, while also investigating the association between mother-infant physiological and behavioral synchrony during their interaction.

For Study 1, secondary data from the control group of a randomized control trial (NCT 03576586) involving full-term mother-infant dyads (n=55) was analyzed. Maternal CB-PTSS and bonding were assessed using the PTSD Checklist for DSM-5 (PCL-5) and the Mother-Infant Bonding Scale (MIBS) at six weeks and six months postpartum, respectively. Infant development was assessed using the Bayley Scales of Infant Development at six months postpartum. At six weeks postpartum, associations were found between a higher total CB-PTSS score and poorer bonding (B=0.134, p=0.017), as well as between higher GS and poorer bonding (B=0.306, p=0.002). Higher BRS at six weeks postpartum was associated with better infant cognitive development at six months postpartum in the unadjusted model (B=0.727, p=0.031).

For Study 2, mother-infant dyads (n=100) were classified into three groups: BRS (n=20), GS (n=46), and non-symptomatic (NS) (n=34) based on maternal self-report on PCL-5. At six months postpartum, mother-infant interactions were video-recorded, and their quality was assessed using the Global Rating Scale. Mothers in the BRS group engaged in more frequent coercions compared to the NS group (B=-1.46, p=0.01, 95%CI=-2.63, -0.36) and showed lower reciprocity in their interactions with their infants compared to the GS group (B=1.21, p=0.03, 95%CI=0.05, 3.37).

For Study 3, a total of 86 mothers and their term infants participated. Like Study 2, PCL-5 was used to assess maternal CB-PTSS, and mother-infant dyads were classified into three groups. During interactions, physiological synchrony was measured using heart rate variability (HRV), while behavioral synchrony (reciprocity) was observed in video recordings. Dyads' physiological synchrony were classified into negative (opposite HRV fluctuations) and positive (same HRV fluctuations). Physiological synchrony was observed between mothers and their infants. Coefficient distributions were not significantly different between CB-PTSS groups in positive ($F(2, 37)=2.08$, $p=0.14$) and negative dyads ($F(2, 37)=0.89$, $p=0.42$). No significant associations between physiological and behavioral synchrony in the positive dyads ($F(1, 33)=1.76$, $p=0.19$), or in the negative ones ($F(1, 34)=0.06$, $p=0.80$) were found.

The finding of the thesis help nurses to better understand the consequences of CB-PTSS on mother-infant relationship and infant development. Nurses can take a more active role in increasing awareness through health education and provide more support to parents. This involves tailoring nursing care plans in collaboration with other healthcare professionals for specialized interventions to improve symptoms and to enhance the mother-infant relationship. However, additional studies are still needed to enhance training and assist nurses in implementing knowledge gained from research findings into practice.

Résumé

L'objectif de ce projet de thèse était d'examiner les associations entre les symptômes de stress post-traumatique maternels liés à l'accouchement (SSPT-A), les relations mère-enfant, ainsi que le développement de l'enfant à six mois post-partum. Les SSPT-A se composent de deux facteurs : les symptômes liés à la naissance (SLN, c'est-à-dire symptômes de reviviscence et d'évitement), et les symptômes généraux (SG, c'est-à-dire symptômes de cognition et d'humeur négatives et d'hyperactivation). Les relations mère-enfant dans cette thèse comprennent : le lien mère-enfant, les interactions et la synchronie (physiologique et comportementale). Dans l'étude 1, l'accent principal était mis sur l'investigation des associations entre les SSPT-A maternel et le lien mère-enfant, avec le développement de l'enfant examiné comme un résultat secondaire. L'étude 2 a abordé les différences dans les interactions mère-enfant dans le contexte des SSPT-A. L'étude 3 visait principalement à explorer la synchronie physiologique entre les mères et les enfants dans le contexte des SSPT-A, tout en examinant également l'association entre la synchronie physiologique et comportementale mère-enfant pendant leur interaction.

Pour l'étude 1, les données secondaires du groupe contrôle d'un essai contrôlé randomisé en double aveugle (NCT 03576586) composé des dyades mère-enfant à terme (n=55) ont été analysées. Les SSPT-A maternels et le lien mère-enfant ont été évalués avec le *PTSD Checklist for DSM-5* (PCL-5) et *le Mother-Infant Bonding Scale* (MIBS) à six semaines et six mois après l'accouchement. Le développement de l'enfant a été évalué à l'aide des *Bayley Scales of Infant Development* à six mois après l'accouchement. A six semaines après l'accouchement, des associations ont été trouvées entre un score total plus élevé des SSPT-A et un lien mère-enfant moins fort (B=0.134, p=0.017), ainsi qu'entre un score plus élevé des SG et un lien mère-enfant moins fort (B= 0.306, p=0.002). Les SLN plus élevés à six semaines post-partum étaient associés à un meilleur développement cognitif de l'enfant à six mois post-partum dans le modèle non ajusté (B=0.727, p=0.031).

Pour l'étude 2, les dyades mère-enfant (n=100) ont été classées en trois groupes : SLN (n=20), SG (n=46), et non-symptomatiques (NS) (n=34) en fonction de l'auto-évaluation maternelle sur le PCL-5. À six mois après l'accouchement, les interactions mère-enfant ont été filmées et ont été évaluée à l'aide de l'échelle *Global Rating Scale*. Les mères du groupe SLN ont été plus souvent coercitives par rapport au groupe NS (B=-1.46, p=0.01, IC95%=-2.63, -0.36) et ont montré moins de réciprocité dans leurs interactions avec leurs enfants par rapport au groupe SG (B=1.21, p=0.03, IC95%=0.05, 3.37).

Pour l'étude 3, un total de 86 mères et leurs enfants à terme ont participé. Comme dans l'étude 2, le PCL-5 a été utilisé pour évaluer les SSPT-A maternelles, et les dyades mère-enfants ont été classées en trois groupes. Pendant les interactions, la synchronie physiologique a été mesurée en utilisant la variabilité de la fréquence cardiaque (VFC), tandis que la synchronie comportementale (réciprocité entre la mère et l'enfant) a été mesurée dans les enregistrements vidéo. La synchronie physiologique des dyades a été classée comme négative (fluctuations opposées de la HRV) ou positive (mêmes fluctuations de la HRV). Une synchronie physiologique a été observée entre les mères et leurs enfants. Les niveaux de synchronie physiologique n'étaient pas significativement différentes entre les groupes SSPT-A dans les dyades positives (F(2, 37)=2.08, p=0.14) et négatives (F(2, 37)=0.89, p=0.42). Aucune association significative entre la synchronie physiologique et comportementale dans les dyades positives (F(1, 33)=1.76, p=0.19) ou dans les négatives (F(1, 34)=0.06, p=0.80) n'a été trouvée.

Les résultats de cette thèse aident les infirmières à mieux comprendre les conséquences des SSPT-A sur la relation mère-enfant et sur le développement des enfants. Les infirmières peuvent jouer un rôle plus actif dans la sensibilisation à travers l'éducation à la santé et fournir un soutien accru aux parents. Cela implique d'adapter les plans de soins infirmiers en collaboration avec d'autres professionnels de la santé pour des interventions spécialisées visant à améliorer les symptômes et à renforcer la relation mère-enfant. Cependant, des études supplémentaires sont encore nécessaires pour améliorer la formation et aider les infirmières à mettre en pratique les connaissances acquises à partir des résultats de la recherche.

List of Abbreviations

APA	American Psychological Association
ARIMA	Autoregressive Integrated Moving Average
BRS	Birth-related Symptoms
CB-PTSD	Childbirth-related Posttraumatic Stress Disorder
CB-PTSS	Childbirth-related Posttraumatic Stress Symptoms
CBT	Cognitive Behavior Therapy
CHUV	Centre Hospitalier Universitaire Vaudois
City BiTS	City Birth Trauma Scale
DSM	Diagnostic and Statistical Manual of Mental Disorders
EPDS	Edinburgh Postnatal Depression Scale
FFSF	Face-to-Face Still-Face
GS	General Symptoms
GRS	Global Rating Scale
HADS	Hospital Anxiety and Depression Scale
HRV	Heart Rate Variability
IBQ-R	Infant Behavior Questionnaire - Revised Very Short Form
IQR	Interquartile Ranges
MAI	Maternal Attachment Inventory
MIAS	Mother Infant Attachment Scale
MIBS	Mother-to-Infant Bonding Scale
MPAS	Maternal Postnatal Attachment Scale
NEG	Negative Emotionality
NS	Non-Symptomatic
ORC	Orienting/Regulatory Capacity
PAS	Positive Affectivity/Surgency
PBQ	Postpartum Bonding Questionnaire
PCL-5	Posttraumatic Stress Disorder Checklist for DSM-5
PDS-F	Post Traumatic Diagnostic Scale
PTSD	Posttraumatic Stress Disorder
RCT	Randomized Controlled Trial
REDCap	Research Electronic Data Capture

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1 Introduction

At the forefront of patient care, nurses and midwives play a pivotal role in providing support for the health and well-being of both mothers and infants (1), including addressing support related to perinatal mental health issues, such as childbirth-related posttraumatic stress symptoms (CB-PTSS) (2, 3). Approximately 30% to 45% of women (4-6) who gave birth experienced that their lives and/or their infants' lives were in danger. A traumatic childbirth experience can potentially lead to CB-PTSS according to the Diagnostic and Statistical Manual of Mental Disorders – 5th Ed (DSM-5), which consist of four symptom clusters: re-experiencing (e.g., repeated, disturbing, and unwanted memories of traumatic childbirth), avoidance (e.g., avoiding memories, thoughts, or feelings related to the traumatic childbirth), negative cognition and mood (e.g., feeling distant from other people), and hyperarousal (e.g., feeling jumpy or easily startled) (7).

Drawing upon the framework of intergenerational transmission of stress- and trauma-related consequences, it is possible that mothers who undergo traumatic birth experiences may inadvertently transmit stress and trauma to their infants through early perinatal care including mother-infant interactions (8, 9). CB-PTSS may affect mothers' behaviors during interactions, transmitting the stress and trauma from mothers to infants. For example, CB-PTSS might be associated more intrusive behavior in mothers, which, in turn, could result in disorganized behavior in infants (8, 10), potentially leading to lower social development outcomes for the child in the future (11). However, the existing literature on the consequences of maternal CB-PTSS on mother-infant relationships and infant development has shown mixed findings and is not as definitive as previously suggested. Furthermore, the available research is limited by the small number of studies (10-19). This inconsistency underscores the need for further investigation into the potential negative consequences of maternal CB-PTSS on mother-infant relationships and infant development.

Moreover, mother-infant physiological and behavioral synchrony during interactions were identified as a protective factor in infant development, improving infant vagal activity and facilitating better biological rhythm and more optimal infant self-regulation during the first years of life (20-22). However, although the critical gap exists in understanding the mother-infant physiological synchrony for mothers experiencing CB-PTSS, to my knowledge, no studies have investigated this matter.

Therefore, in light of these gaps in the literature, this thesis aims to provide a comprehensive examination of maternal CB-PTSS and its associations with mother-infant relationships (bonding, interactions, physiological and behavioral synchrony) and infant development. By understanding these associations, nurses and other healthcare professionals can tailor their support to address the specific needs of mothers and infants affected by CB-PTSS.

2 Literature Review

This chapter comprehensively summarizes studies related to maternal CB-PTSS, mother-infant bonding, mother-infant interactions, mother-infant synchrony (physiological and behavioral), and infant development, highlighting the gaps in the literature. With the assistance of a librarian from the Faculty of Biology and Medicine-CHUV library, we established the syntax and research strategy for the literature search (for further details, see Appendix A). Several databases relevant for the research topics were searched without limitation with regards to publication years, such as PubMed with MeSH terms, APA PsycInfo, and Google Scholar for articles written in English. Related articles were also identified through manual search based on the reference lists.

2.1 Traumatic birth

About 30-45% of women report having perceived childbirth as traumatic (4-6). According to Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, (DSM-5) traumatic childbirth may be considered to have occurred if there is a perceived danger to the life of the mother and/or the infant, or in cases where severe physical harm has been sustained (2, 3). Alternatively, traumatic childbirth can also be defined as distressing experience that could include, interactions and/or events during the birthing process that elicit overwhelming emotional responses, potentially leading to adverse effects (23).

2.1.1 CB-PTSD and CB-PTSS

Traumatic childbirth can result in the development of childbirth-related posttraumatic stress disorder (CB-PTSD) (3), which stems from posttraumatic stress disorder (PTSD). PTSD can occur following exposure to actual or threatened death, serious injury, or sexual violence (2). CB-PTSD refers specifically to the psychological symptoms that emerge after experiencing a traumatic birth (3). A recent study discovered that mothers' perception of their own lives or their infants' lives being in danger was prospectively linked to maternal CB-PTSS and probable CB-PTSD up to six months postpartum (24).

Similar to PTSD, CB-PTSD consists of four symptom clusters: re-experiencing, avoidance, negative cognition and mood, and hyperarousal (2). Mothers are classified as experiencing CB-PTSD if they have at least one re-experiencing, one avoidance, two negative cognitions and mood, and two hyperarousal symptoms related to the traumatic childbirth event with symptoms lasting for at least one month (2, 3). On the other hand, mothers who experience significant levels of symptoms but do not meet the diagnostic criteria for PTSD, as explained beforehand, are classified as experiencing CB-PTSS (2, 3).

Maternal CB-PTSS can only be measured minimum at one month postpartum when the symptoms start to develop (2, 25). CB-PTSS or CB-PTSD can be identified and assessed via self-report questionnaires such as Posttraumatic Checklist for DSM-5 (PCL-5) (26) which was initially developed to assess PTSD experience by war veteran. However, PCL-5 also have been used in several studies for CB-PTSD or CB-PTSS by adjusting the traumatic event to childbirth (13, 27). Another scale that can be used is Post Traumatic Diagnostic Scale (PDS-F) (28) which is also not specific to measured CB-PTSD or CB-PTSS but had been used in study focusing on CB-PTSD (12). Moreover, another questionnaire used to assess CB-PTSD or CB-PTSS is the City Birth Trauma Scale (City BiTS), specifically developed to evaluate these symptoms (29). Aside from questionnaires, CB-PTSD also can be measured through clinician-rated interview, named Clinician-Administered PTSD Scale for DSM-5 (CAPS), which is considered the gold standard for measurement (30).

The reported prevalence of maternal CB-PTSD was 4.7% while maternal CB-PTSS was reported to be 12.3% (31). These prevalence rates are largely based on research conducted

in developed countries that measured with various self-report (e.g., City BiTS, PCL-5) and interview (i.e., CAPS) (31). CB-PTSS not only negatively affect mothers and their children but also their families (3) as also explained by Beck (32) in the Middle Range Theory of Traumatic Childbirth (see details in section 3.1). With approximately 701 million births worldwide from 2015 to 2020, more than 86 million women and their families are estimated to be affected by CB-PTSS every year (33).

Moreover, perinatal mental health problems have significant economic impacts (34-36). In the United States, perinatal mental health cost 31800 USD per year per affected mother–child dyad which amount to 14 billion USD per year (34), and 6.6 billion GBP in UK (35). In South Africa, lifetime costs of perinatal mental health are up to 2.9 billion USD per annual cohort of births with 1.8 billion USD linked to losses in quality of life, 1.1 billion USD to losses in income, and 3.5 million USD to public sector costs (36). While no other studies specifically addressed the cost of CB-PTSD outside the general terms of perinatal mental health, they are indicative and underline the importance of better understanding and tackling situations that can trigger mental health problems, such as traumatic births (36).

2.1.2 Classifications of symptom clusters

The four symptom clusters of CB-PTSS can be classified into two factors: birth-related symptoms (BRS, i.e., re-experiencing and avoidance symptoms) and general symptoms (GS, i.e., negative cognition and mood and hyperarousal symptoms) (37, 38). It is conceivable that various facets of PTSS may associate differently with parents' relationship with their children and child outcomes. For instance, re-experiencing symptoms (BRS) were linked to less positive infant outcomes, specifically in motor development, although only small significant association observed (11). Moreover, GS were associated with poorer mother-infant bonding (39-41) while BRS was not. While research on different factors of CB-PTSS or CB-PTSD remains limited to date, broadening the perspective to include PTSD in other contexts could offer valuable insights. For example, a study involving male war veterans found that avoidance symptoms (BRS) were associated with lower parent–child relationship satisfaction (42). While this research is not directly related to childbirth in mothers, it underscores the importance of understanding how different factors of PTSD symptoms, can impact parent-child relationships. In this thesis, the consequences of CB-PTSS on mother-infant relationship and infant development were investigated further while taking CB-PTSS factors (i.e., BRS and GS) into consideration.

2.2 Mother-infant relationships

Mother-infant relationship is a broad term often used to describe mother-infant bonding and mother-infant interactions (17). Within these interactions, synchrony involving both physiological and behavioral aspects can be observed (43). The mother-infant relationship at six months old typically develops through increased mutual interaction, bonding, and the establishment of a secure attachment (20). Infants at this age may demonstrate greater responsiveness to their mother's cues, engage in reciprocal communication, and display a growing sense of trust and comfort in their interactions with their caregiver (20)

2.2.1 Mother-infant bonding

Mother-infant bonding is defined as the unidirectional tie from the mother to her infant that grows and endures over time (44-46). In a systematic review and meta-synthesis, it is mentioned that bonding and attachment are often used interchangeably, but they represent distinct concepts (46). According to this review (46), parent-infant bonding pertains to the emotional connection and internal experiences of parents in their relationship with their infants, extending even when the infant is not physically present, such as during prenatal stages (47). On the other hand, mother-infant attachment, refers to the infant's first relational

experience with their mother, involving the infant's sense of security and trust in the caregiver (48).

Bonding has been linked to better parenting skills, such as reduced parenting stress, increased parental sensitivity, and greater parental involvement (46). Consequently, higher levels of bonding were linked to better child outcomes including better general adaptive behavior (independence), better social−emotional competence, better emotional stability, and social approach behavior (49). Since mother-infant bonding is a subjective maternal experience, instruments mostly used are questionnaires completed by mothers, including: Maternal Attachment Inventory (MAI) (50), the Mother Infant Attachment Scale (MIAS) (51), the Maternal Postnatal Attachment Scale (MPAS) (52), the Postpartum Bonding Questionnaire (PBQ) (53), and the Mother-to-Infant Bonding Scale (MIBS) (54).

2.2.1.1 Factors associated with mother-infant bonding

In general, there are several factors negatively affecting mother-infant bonding, including maternal mental health problems (46) such as CB-PTSS (12), depression symptoms (54-56), anxiety symptoms (12, 40, 57), and history of trauma (58). Parity status is also associated with mother-infant bonding, i.e., being primipara is associated with lower mother-infant bonding (59). Moreover, studies in healthy mothers found that infant temperament such as positive emotion (infant smiling) is associated with mother-infant bonding where (60, 61). Another factor associated with bonding is the attachment style of the mothers, where avoidant maternal attachment style was associated with anger and rejection toward the infants mediated by CB-PTSS, while an anxious maternal attachment style was associated with infant-focused anxiety mediated by postpartum depression (62).

2.2.1.2 Mother-infant bonding and CB-PTSS

The studies on the association between maternal CB-PTSS and mother-infant bonding are inconsistent. A prospective cohort study found that maternal CB-PTSS at one month postpartum may have adverse effects on mother-infant bonding at three months postpartum, such as (12). Another study, that not only included mothers but also fathers, supported this finding where CB-PTSS had a direct effect on the parent-infant bonding measured cross-sectionally one to 24 months postpartum (63). Further insight into the mechanisms underlying this association was provided by Hairston et al. (62). They who identified that CB-PTSS mediated the link between mothers' avoidant attachment style and lower mother-infant bonding (PBQ, i.e., greater rejection of infant and anger toward infant) cross-sectionally at four to 12 weeks postpartum) (62).

There are several studies (13, 57, 64) used the term 'attachment' rather than 'bonding' to explore the concept of how mothers perceive their relationship with their infants. Despite this difference in terminology, I included them here, as they investigate the same underlying concept. A cross sectional study found that maternal "attachment" was lower in CB-PTSD than in non-childbirth PTSD and no CB-PTSD up to six months postpartum (13). Moreover, another study found that mothers meeting full or partial criteria for CB-PTSD perceived their relationships as less optimal (57). They also perceived their infants as less warm and more invasive as measured at six weeks (57). However, another study involving mothers with infants under 12 months of age, found that maternal CB-PTSS did not independently predict perceptions of the mother–infant bonding but mediated by maternal postpartum depression (64). Instead, postpartum depression mediated the indirect relationship between CB-PTSS and the mother–infant bonding (64)

The complexity of the relationship between CB-PTSS and mother-infant bonding becomes more apparent when considering the two factors of CB-PTSS (i.e., GS, BRS). While the total

score of CB-PTSS did not mediate the association between maternal personality factor (i.e., vulnerability and resilience) and mother-infant bonding, GS mediated this association, while BRS only predicted fewer bonding difficulties measured cross-sectionally at 0-13 months postpartum (39). Another study found similar results where GS had a direct effect on bonding and an indirect effect on bonding via maternal depressive symptoms and that BRS did not have any effect on mother-infant bonding measured cross-sectionally at 0-12 months postpartum (41). Moreover, maternal avoidant attachment had indirect effects on mother-infant bonding through GS measured at two months postpartum while maternal anxious attachment also had indirect effects on bonding measured at six months postpartum through GS. BRS symptoms were not associated with bonding (40).

Despite recent studies aimed at understanding the association maternal CB-PTSS and mother-infant bonding as explained above, this connection appears inconsistent and characterized by mixed findings particularly regarding the BRS factor and its association with mother-infant bonding. Therefore, more research is needed to investigate the association between mother-infant bonding and maternal CB-PTSS, analyzing CB-PTSS as total score and as two factors (i.e., BRS, GS) which will be addressed in Study 1 of this thesis.

2.2.2 Mother-infant interactions

A good quality of mother-infant interactions is indicated by reciprocal, positive affect, and engaging dyadic interactions (65). Aside from that, another aspect measured during the interactions is maternal sensitivity. Maternal sensitivity is defined as a mother's ability to understand her infant's cues and to adapt her behavior (22, 66-68), thus facilitating her infant's emotion regulation. Infant emotion regulation is defined as the ability of infants to manage emotions and behaviors in response to environmental pressure (69, 70). Maternal sensitivity was linked to infant attachment security (i.e., secure, anxious, avoidant, and secure) (71). Consequently, good mother-infant interactions were found to be associated with higher infant cognitive development at 12 months old (65). On the other hand, the lack of maternal sensitivity in the mother-infant interactions can negatively influence subsequent infant socioemotional development, such as behavior problems, and affects infant regulation, or infant social competence (70).

The assessment of mother-infant interactions includes a macro-level measure, which evaluates the overall quality of interactions between the dyad and a micro-level measure, which involves a detailed examination of interactions in very small time segments (72, 73). The macro-level approach is typically regarded as more advantageous and suitable for comprehensively understanding maternal behaviors in response to infant cues, providing a broader and more comprehensive evaluation (72). Instruments for macro-level measurement include the Global Rating Scale (GRS) (74), Emotional Availability Scale (75), and CARE-index (76). GRS includes nine subscales which assess infant behaviors (two scales), maternal behaviors (five scales), and joint behaviors (two scales) (further details, see section 5.2.2.2) (74). Emotional Availability Scale has four subscales, i.e., sensitivity, intrusiveness, constructing, and non-hostility (75). The CARE index consists of seven subscales, i.e., facial expression, verbal expression, position, affection, turn-taking, control, and choice of activity (76). These subscales were evaluated and contributed to scores on three adult scales (sensitive, controlling or unresponsive) and four infant scales (cooperative, difficult, compulsive and passive) (76).

Several procedures commonly used in the literature to assess mother-infant interactions include free-play, and the Face-to-Face Still-Face paradigm (FFSF) paradigm (10, 14, 77, 78). In the free-play task, mothers and infants are instructed to interact freely as they would typically do at home (14, 77). FFSF paradigm is a standardized stress paradigm consisting of three phases: the free-play phase, the still-phase, and the reunion phase, designed specifically to assess emotional regulation of the infants (78).

2.2.2.1 Mother-infant interactions and CB-PTSS

Mothers with CB-PTSS may be at risk of having problems developing good interactions with their infants because they were observed to be more controlling, more intrusive and less sensitive during interactions (10, 27, 79, 80). For instance, a study by Ionio and Di Blasio (10) in 19 healthy dyads found that persistence of maternal CB-PTSS (measured at two days and two months postpartum) was associated with infant crying and disorganized behavior in three-month-olds during the play phase. The infant averted their gaze during the still-phase of FFSF paradigm procedure (78), while the mothers tended not to look directly at their infant and touched their infant more (10).

Furthermore, a study involving mother-infant dyads (47 preterm infants and 25 full-term infants) found that mothers with infants born before 34 weeks gestation and those with CB-PTSS were less sensitive and more controlling in interactions measured at six months postpartum, with CB-PTSS retrospectively measured at 18 months of age (79). With similar participants and timeline, Forcada-Guex et al. identified distinct interactional patterns in dyads. Groups with high maternal CB-PTSS displayed a "controlling mother and compliant infant" pattern, while those with low CB-PTSS showed a heterogeneous pattern, which still included instances of maternal control and reduced sensitivity mixed with maternal unresponsiveness, reinforcing the adverse effects of CB-PTSS on interaction dynamics (80). In contrast, dyads with full-term infants showed a more positive “sensitive mother and cooperative infant” pattern, underscoring the negative impact of maternal CB-PTSS on mother-infant interactions.

Further evidence supporting the negative effects of CB-PTSS on mother-infant interactions comes from Feeley et al. who studied 21 dyads with infants previously hospitalized in NICU due to very low birth weight (<1500 grams) (14). Their findings indicated that mothers with CB-PTSS were less sensitive and less effective in structuring the interactions with their infant at six months old postpartum (14), supporting that maternal CB-PTSS is associated with reduced maternal sensitivity. Additionally, less sensitivity in mothers with CB-PTSS was also confirmed by the study by Rousseau et al. involving 192 healthy dyads at four months old postpartum (27).

However, a study by Parfitt et al. (77) found that CB-PTSS did not show a significant association with mother-infant interactions but rather, only prenatal anxiety symptoms were associated with mother-infant interactions at three months postpartum. Different findings may be explained by differences in measurement, especially for mother-infant interaction measures. The study by Feeley et al. (14) used the Emotional Availability Scales while several studies (77, 79, 80) measured the interactions with the CARE index. Finally, the study by Ionio and Di Blasio (81) used the FFSF paradigm to observe mother-infant interactions (78) and did not control for maternal depression. Moreover, none of these studies examined maternal CB-PTSS as two factors (i.e., BRS, GS). Therefore, further research is needed to understand the mother-infant interactions in the context of CB-PTSS, particularly focusing on the two factors of CB-PTSS which will be addressed in Study 2 of this thesis.

2.3 Synchrony

During mother-infant interactions, dyadic synchrony can be observed. Dyadic synchrony is defined as joint and coordinated navigation of moment-by-moment interactions between the mother and infant, where their behavioral and physiological regulation patterns coordinate in a smooth and online, responding to each other's cues and signals in a coordinated manner (82).

2.3.1 Behavioral synchrony

Mother-infant behavioral synchrony can be measured through observation of both, the infant and mother, in terms of emotional expressions, gaze, touch, vocalizations, and reciprocal adaptation (83). Behavioral synchrony or reciprocity is one aspect of the measure observed in mother-infant interactions, as detailed in section 2.2.2. Therefore, similar to interactions, the evaluation of mother-infant behavioral synchrony can be conducted through both macro and micro-analysis (73). In macro analysis, scales are more general and consist of subscales such as maternal sensitivity and emotional tone. Thus, their purpose extends beyond measuring behavioral synchrony alone. For example, in the GRS instrument, only the reciprocity subscale specifically assesses mother-infant behavioral synchrony (74). However, in a micro analysis, synchrony between mother-infant dyad is observed in time series. Each second of behavior is coded within each mother-infant dyad. This observation encompasses movements, gazes, and vocalizations during play, whether infants lead and mothers follow or the other way around (73).

2.3.2 Physiological synchrony

Physiological synchrony can be measured through several methods, one of which is heart rate variability (HRV) (43). This synchrony is observed as the heart rhythms of mothers and infants adapt and coordinate with each other within a lag of less than one second during interactions in healthy dyads (84, 85).

2.3.2.1 Physiological regulation

HRV is considered as an important indicator of physiological regulation to assess overall wellbeing, including in infants (86). It is one of the markers of the autonomic nervous system that measures the oscillations between consecutive instantaneous heart rates and oscillation intervals of the adjacent QRS complex, indicative of ventricular depolarization resulting from an electrical impulse (87). Furthermore, HRV reflects vagal tone activity, which is known to be an indicator of emotion regulation functioning (84, 88, 89). Vagal activity encompasses both afferent (sensory) and efferent (motor) fibers that stimulate organs in the body, including the gastrointestinal and cardiovascular system (90). HRV can be measured with electrocardiogram (ECG) (84) and analyzed with several methods: time domain, frequency domain, time–frequency domain and nonlinear' methods (91).

In adults and infants, high HRV is generally related to positive health outcomes (92). On the other hand, reduced HRV has been linked to poorer health outcomes, including conditions such as high blood pressure and hyperglycemia, because it can indicate problems in autonomic regulation (93). Moreover, studies in adults found that lower HRV is related to mental health problems, such as PTSD and depression (94, 95). A systematic review found that mothers with depression showed lower HRV compared to healthy mothers (96). Further, infants of mothers with higher stress levels or previous depression had lower HRV compared to infants born to mothers without a history of depression and with less stress (97). Not only in depressed mothers, lower HRV is also associated with other psychopathologies including anxiety and somatic symptom disorders (98, 99). However, to date, HRV in the context of maternal CB-PTSS has not been investigated so far.

2.3.2.2 Synchrony (physiological and behavioral) and CB-PTSS

Little is known about mother-infant physiological synchrony in high-risk populations (e.g., mothers with mental health problems). Although some studies with mixed results have been conducted in dyads with maternal depression, none have examined physiological synchrony in the context of maternal CB-PTSS. For example, a study by Field et al., involving a total of 16 mother-infant dyads, found no difference in physiological synchrony between dyads with

maternal depression and those without (100). In contrast, another study with a larger sample size of 94 dyads, found discordance in physiological synchrony of dyads with maternal history of major depressive disorders compared to dyads without (101). The differences in findings may be attributed not only to variations in sample size but also to methodological differences, as the former study focused on mothers and their three-month-old infants (100). while the latter study included older children aged 7 to 11 years (101). Furthermore, other factors such as the assessment of depression levels in mothers, may need to be taken into account in addressing different results.

On the other hand, another study involving 68 mother-infant dyads found that dyads with anxious mothers, demonstrated increased physiological synchrony compared to those with less anxiety (89). Highly anxious mothers may encounter difficulties in managing stress and regulating their arousal levels, especially in situations where both they and their infants are experiencing heightened arousal (89). Consequently, the presence of heightened physiological synchrony within such dyads does not consistently correlate with improved maternal mental well-being (89). Nevertheless, despite these insights, research investigating physiological synchrony in the context of maternal mental health is still lacking.

Furthermore, the mother-infant behavioral synchrony which is one of the observed subscales during mother-infant interactions, has not been specifically mentioned in previous research (10, 27, 79, 80) in relation to maternal CB-PTSS. They have primarily focused on differences in terms of maternal sensitivity and intrusiveness, as explained in section 2.2.2.1. Additionally, it is unknown how these dyads behavioral synchrony related to dyadic physiological synchrony. Therefore, the association between mother-infant physiological synchrony and behavioral synchrony will be addressed in Study 3.

Hence, to the best of our knowledge, there are no studies that examined the mother-infant physiological synchrony in the context of maternal CB-PTSS. Therefore, Study 3 investigated whether there is physiological synchrony between maternal HRV and infant HRV during social interactions in the context of CB-PTSS at six months postpartum. Additionally, the study explored whether there was an association between mother-infant physiological and behavioral synchrony.

2.4 Infant development

The first year of life is an important milestone, as infants go through a robust development stage across multiple domains (i.e., brain maturation, language development that predicts long-term child development outcomes (102-104). Starting at age three months old and continuing until six months old, infants begin to develop coordination or social exchange of interactive behaviors across multiple modalities including visual, vocal, affective, and touch. By approximately nine months of age, infants' social interactions exhibit maturation and progress toward true reciprocity (20).

Infants of mothers experiencing mental health problems may have poorer infant development outcomes (105). This could be due to the influence of mothers' mental health symptoms on their behavior that may be less sensitive during interactions with their infants (14, 27). Infants are thought to respond to maternal unresponsiveness through avoidance behaviors, including looking away, crying, and emotional disengagement, as a regulatory mechanism to mitigate the adverse effects of negative interactions, which may negatively impact their socio-emotional development (11, 81). The assessment of infant development typically encompasses cognitive, language, and motor domains (106). The Bayley Scales of Infant Development III (BSID-III) have been commonly utilized in previous studies to measure child development up to 36 months of age (14, 15, 106).

2.4.1 Infant development and CB-PTSS

To my knowledge, only three studies investigating the relationships between maternal CB-PTSS and child development have been published, with mixed results, with only one study exploring infant development at six months (11, 14, 15). When measured prospectively, CB-PTSS were associated with greater negative social development outcomes, especially for boys (11), and lower cognitive outcomes (15), but not when measured cross-sectionally at six months postpartum (14). Differences in the methodology of these three studies (i.e., use of various self-report questionnaires, distinct time points of data collection, and different sample sizes) might contribute to these mixed results. One prospective study used a maternal self-report questionnaire, Ages & Stages Questionnaire, to measure child development at two years old (11), while the other two studies (with cross-sectional and prospective designs, respectively) used the Bayley Scales of Infant Development III to measure infant development at six months and 17 months, respectively (14, 15). Moreover, participants in the study by Feeley et al. were very low birthweight infants who were hospitalized in a neonatal intensive care unit (14). It is thus evident that research on the association between maternal CB-PTSS and infant development is limited and that more evidence is needed.

2.5 Thesis aims

2.5.1 Study 1

The main aim of Study 1 was to investigate the associations between maternal CB-PTSS and mother-infant bonding (cross-sectionally and prospectively). The secondary aim was to investigate the associations between maternal CB-PTSS and infant development (cross-sectionally and prospectively). We hypothesized that there were negative associations between maternal CB-PTSS and mother-infant bonding, and between maternal CB-PTSS and infant development.

2.5.2 Study 2

Study 2 aimed to compare mother-infant interactions between three groups (i.e., non-symptomatic, GS, and BRS) at six months postpartum. We hypothesized differences in mother-infant interactions between groups.

2.5.3 Study 3

The aim of Study 3 was to investigate if there is physiological synchrony between maternal HRV and infant HRV during social interactions in the context of CB-PTSS at six months postpartum. We hypothesized there was mother-infant HRV synchrony and that HRV synchrony differed between CB-PTSS groups. The second aim was to investigate the association between mother-infant physiological and behavioral synchrony. We hypothesized a significant association between mother-infant physiological and behavioral synchrony.

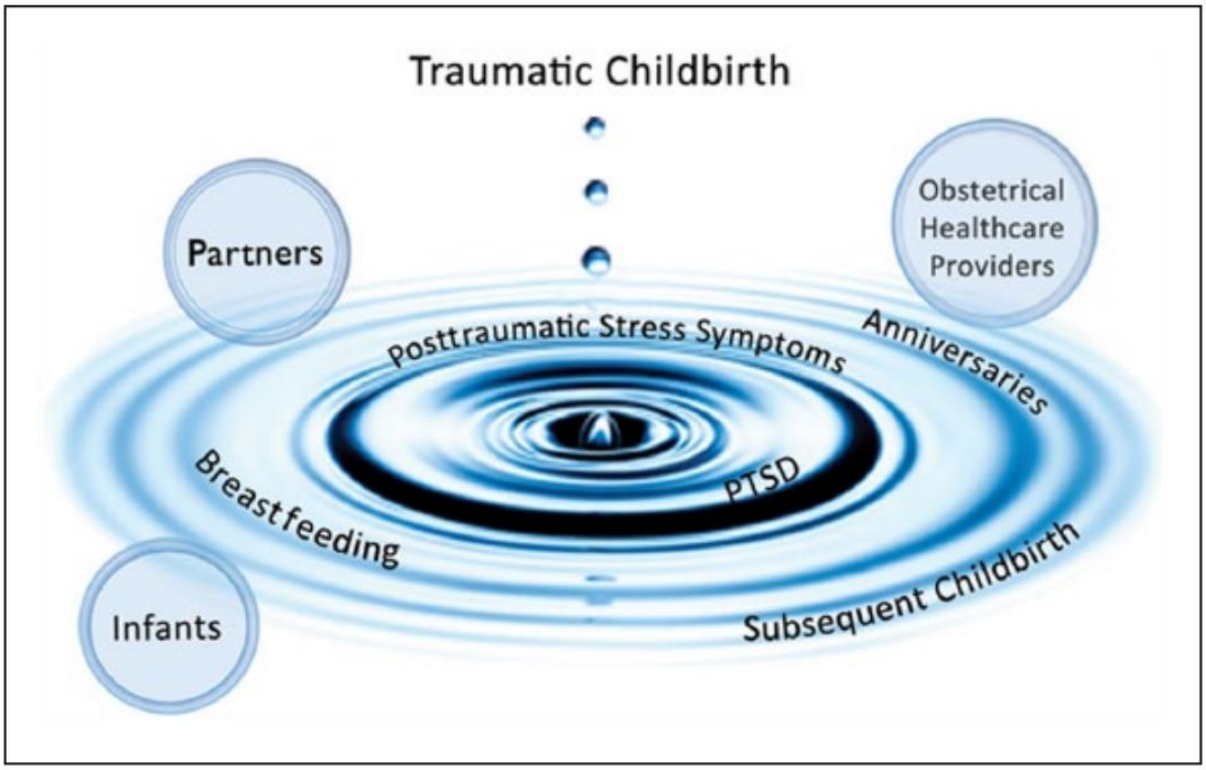
3 Theoretical framework

The following chapter introduces the conceptual frameworks used as theoretical foundations for this PhD thesis.

3.1 Nursing middle range theory of traumatic childbirth

This PhD research is based on the middle range theory of traumatic childbirth by Beck (32). This middle range theory of traumatic childbirth was developed using Morse's method of theoretical coalescence, connecting 14 qualitative individual studies. Figure 1 describes middle range theory that illustrate the consequences of traumatic childbirth are like a pebble dropped in the water, causing a ripple effect that could be negative or positive, depending on how the actions by the healthcare providers were perceived by mothers during childbirth process (32).

Figure 1. Middle range theory of traumatic childbirth (reproduced with the permission of the copyright holders).



The theory explained traumatic birth as an event that occurs during childbearing, where a woman perceives her childbirth as traumatic because she did not feel cared for, did not feel respected during the birthing process, experiencing terror, helplessness, and loss of control. The theory identified negative consequences of traumatic childbirth on mother–infant interactions, bonding, and infant development outcomes, breastfeeding, subsequent childbirth, and the anniversary of birth trauma. This theory also explained secondary traumatic stress, highlighting the impact of traumatic childbirth on partners and clinicians (an issue which is not included in this thesis).

The middle-range theory of traumatic childbirth framework was used for this thesis because it aligns well with the focus on the consequences of traumatic childbirth on mother-infant relationships and infant development. Based on this theory, maternal CB-PTSS can interfere

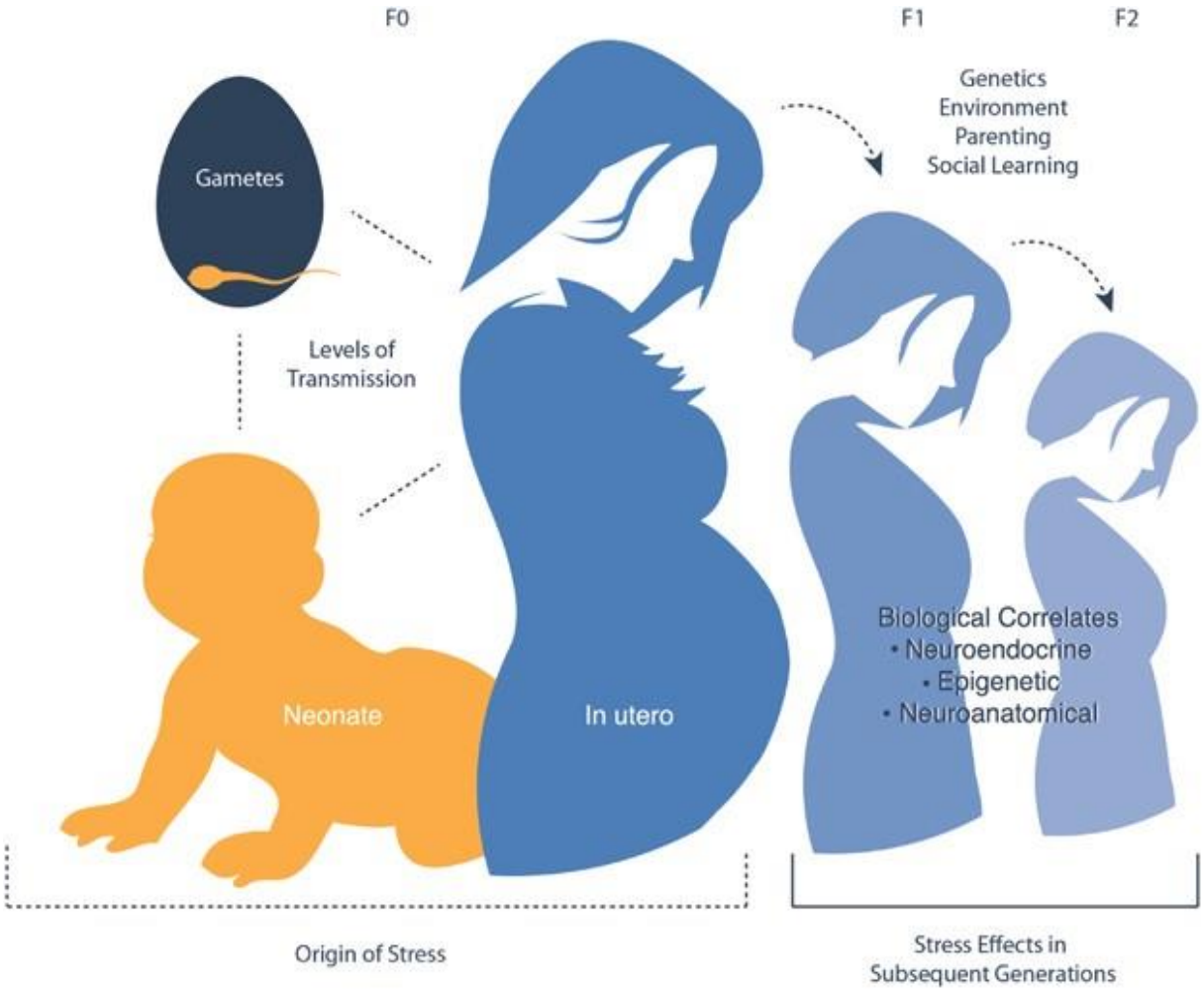
with mother–infant interaction because some women may avoid reminders of their birth trauma, making them emotionally unavailable. The theory highlights that impaired mother–infant interactions may be one of the first indicators of a traumatic birth. It recommends that observing mothers' interactions with their infants while they are still in the postpartum unit to provide insight into whether they have experienced a traumatic birth.

Moreover, Beck explains that traumatic birth could negatively affect infants' cognitive and emotional development, although further discussion is needed on the mechanism and timing of these effects, which were not addressed in the framework. Beck also assumes that maternal CB-PTSS may negatively impact interactions with infants, similar to postpartum depression. She concludes the theory by stating that still many studies need to be done on this theory of traumatic childbirth, including intervention studies focus on improving mother–infant interactions. However, before embarking on intervention studies, it is important to understand how symptoms are associated with mother–infant interactions beyond emotional unavailability. By better understanding the consequences of traumatic birth, nurses and midwives can support mothers to mitigate unpleasant experiences during childbirth and identify the necessary support for mothers and their families afterward.

3.2 Intergenerational transmission of stress and trauma

Another framework used in my study is the intergenerational transmission of stress and trauma framework (8) that complements Beck's theory, explaining the mechanisms of how traumatic childbirth consequences may be transmitted to the infants. This framework aids in understanding how exposure to extreme trauma can have behavioral and biological consequences long after the event has occurred. Figure 2 illustrates the mechanism by which stress and trauma can be transmitted via biological changes in gametes of the parents, the gestational uterine environment, and the early period of postnatal care (8, 9). This thesis explores the transmission of a traumatic childbirth experience of mothers to their infants through the latter mechanism.

Figure 2. Mechanisms of intergenerational transmission of stress and trauma (reproduced with the permission of the copyright holders).



The hypothesis of intergenerational transmission of stress- and trauma-related consequences mostly relies on observational date from animal studies. In the animal studies, early postnatal care, for example separation from the offspring, can result in long-lasting changes (neural, hormonal, cognitive, and behavior) in the offspring. Moreover, this framework hypothesized that a high level of stress and trauma can affect the brain development of the offspring that later can be reflected in decreased cognitive abilities.

Therefore, in this thesis, the associations between maternal CB-PTSS, mother-infant relationship, and the infant outcomes were investigated. This theoretical framework facilitated the formulation of hypotheses for three studies.

4 Methods

Table 1. Research questions, designs, and samples.

Study	Aims	Design	Total sample size
1	a. To investigate associations between maternal CB-PTSS and mother-infant bonding. b. To investigate the associations between maternal CB-PTSS and infant development.	Cross-sectional at six weeks postpartum Cross-sectional at six months postpartum Prospective at six weeks and six months postpartum	55 dyads
2	To investigate the differences in mother-infant interactions among groups (i.e., BRS, GS, NS) in the context of maternal CB-PTSS.	Cross-sectional at six months postpartum	100 dyads
3	a. To explore physiological synchrony between maternal HRV and infant HRV during social interactions (i.e., free-play) in the context of CB-PTSS. b. To investigate the association between mother-infant physiological and behavioral synchrony.	Cross-sectional at six months postpartum	86 dyads

Table 1 above provides an overview of the aims, study designs, and sample sizes of the three studies included in this PhD thesis on the mother-infant relationship and infant development in the context of maternal CB-PTSS.

5 Thesis studies

This section presents the three articles published or in the process of publication (under review and submitted). The ethical approval for Study 2 and Study 3 was included in Appendix B. For Study 1, ethical approval was obtained as part of the original study from which the data were derived (107).

5.1 Study 1: Maternal Childbirth-Related Posttraumatic Stress Symptoms, Bonding, and Infant Development: A Prospective Study

This study was published in Journal of Reproductive and Infant Psychology in 2023 and the original published **article can be found in Appendix C.**

5.1.1 Aims

This study aimed to investigate the prospective and cross-sectional associations between 1) maternal CB-PTSS and mother-infant bonding and 2) maternal CB-PTSS and infant development. We hypothesized higher maternal CB-PTSS would be associated with poorer mother-infant bonding and lower scores of infant development.

5.1.2 Methods

5.1.2.1 Participants

This study is a secondary analysis of data from the control group of a randomized controlled trial (RCT) study that aimed to test the efficacy of an early brief behavioral intervention including a visuospatial task to prevent maternal CB-PTSS (NCT 03576586) (107). In our study, two time points were used: six weeks postpartum (T1), and six months postpartum (T2). The current study included 55 mother-infant dyads from the RCT control group (107). To be eligible for the current study, mothers were required to be ≥18 years old and have undergone an unplanned cesarean section. Additionally, they were required to have fluent French-speaking skills and have given birth to a healthy infant at ≥37 weeks of gestation, up to approximately six months old at the time of recruitment.

Participants completed online maternal-report validated and standardized questionnaires (using the Research Electronic Data Capture (REDCap) software) at T1 measuring maternal CB-PTSS, mother-infant bonding, and covariates (depression and anxiety symptoms, infant temperament, history of trauma). At T2, participants were contacted again through a phone call, a SMS message, or email to fill in the same online questionnaires and to arrange an appointment to assess infant development. Infant development at T2 was assessed at the hospital via a clinician-administered standardized observational assessment. Sociodemographic data were assessed by maternal-report questionnaire and medical data were extracted from hospital records.

5.1.2.2 Instruments

Maternal CB-PTSS was measured with PCL-5 (26), a 20-item self-report questionnaire assessing PTSS over the past month. The traumatic event referred to childbirth. Participants responded using a Likert scale from 0 (not at all) to 4 (extremely), with a higher score indicating more maternal PTSS (26). PCL-5 BRS consists of items 1 to 8, and 10 to 11. PCL-5 GS consists of items 9, and 12 to 20 (26, 37, 38). The French version of the PCL-5 showed strong validity (108). In our study, Cronbach's alpha at T1 was 0.89 and at T2 was 0.90. For the subscale BRS, Cronbach's alpha was 0.90 at T1 and 0.89 at T2. For the subscale GS,

Cronbach's alpha at T1 was 0.81 and at T2 was 0.88; all the above indicating good internal consistency.

Mother-infant bonding was measured with the MIBS, a self-report questionnaire consists of 8 items evaluating mothers' feelings toward their infants in the first few weeks after birth (54). The MIBS has been used in previous studies, including to measure mother-infant bonding at six months postpartum (12, 61, 109). It has a fair rating in terms of readability, easy to understand, and is acceptable and feasible, given that MIBS can be completed under five minutes (110). Items are rated on a 4-point Likert scale ranging from 0 (very much) to 3 (not at all) for items 1, 4, and 6, and on a reversed scale for the remaining items, with a higher value indicating poorer bonding. Moreover, the French version of the MIBS has been validated and showed an alpha score of 0.71 (111). In our study, the Cronbach alpha at T1 was 0.55 and at T2 was 0.52, indicating low internal consistency. After removing item 2, which had a low correlation, Cronbach alpha increased to 0.67 at T1 and to 0.60 at T2. Low internal consistency of MIBS (0.68) was also observed in another study, even though this was a Swedish version of MIBS (112).

Infant development was assessed with the Bayley Scales of Infant Development, 3rd edition (Bayley III) (106), which encompasses cognitive, language, and motor subscales. The Bayley III is widely used instrument for assessing infant development (113). Raw scores from each scale were transformed into three standardized scores with a higher score indicating better development in three domains. The scales were administered in French by trained members of the research team based on a standardized protocol (107). Bayley Scales have been standardized and extensively reviewed for its psychometric quality and tested for reliability (r = 0.86 - 0.93) and validity using large samples of children with and without developmental delay (106).

Regarding maternal psychological vulnerabilities, maternal depression and anxiety symptoms were used as covariates for both outcomes. Maternal depression symptoms were measured with the Edinburgh Postnatal Depression Scale (EPDS), a self-report questionnaire evaluating the severity of postnatal depression symptoms over the past week (114). The 10 items are scored on a 4-point Likert scale from 0 to 3, with a higher total score indicating higher severity. The French version of the EPDS has been validated (115). The Cronbach alpha in our study when measuring at T1 was 0.80 and at T2 was 0.86, which demonstrated good internal consistency.

Anxiety symptoms were measured with the anxiety subscale of the Hospital Anxiety and Depression Scale (HADS-A). This self-report questionnaire consists of 7 items evaluating the severity of postnatal depression symptoms over the past week (116). Items are scored on a 4-point Likert scale from 0 to 3, with a higher total score indicating higher anxiety. The French version of the HADS, has been previously validated (117). The Cronbach alpha in our study when measured at T1 was 0.62 and at T2 was 0.81, which is acceptable.

Infant temperament, as a covariate for the mother-infant bonding outcome, was measured with a maternal self-report instrument named the Infant Behavior Questionnaire - Revised Very Short Form (IBQ-R) consists of 37 items assessing the frequency of certain infant behaviors during the previous two weeks (118). Good psychometric properties were reported for this questionnaire (118). IBQ-R has three factors: Negative Emotionality (NEG), Positive Affectivity/Surgency (PAS), and Orienting/Regulatory Capacity (ORC). Based on previous studies, we only considered positive temperament and negative temperament as potential covariates for bonding (60, 61). Items are scored on a 7-point Likert scale from 1 (never) to 7 (always), with a higher score indicating higher negative behavior (in NEG factor) or higher positive behavior (in PAS factor). There was no validated French version of the IBQ-R available. The forward-backward method was therefore applied for cultural adaptation and French translation as part of START study (107). The Cronbach alpha in our study for

positive temperament was 0.75 and for negative temperament was 0.75, indicating moderate internal consistency.

Medical covariates, i.e., Apgar score (rapid standardized assessment of neonates after birth to determine the need for immediate resuscitation intervention (119)) at 5 minutes, parity status, and sex of the infant were extracted from medical records. History of trauma, civil status, and education levels were measured via a self-report sociodemographic questionnaire.

5.1.2.3 Statistical Analyses

The statistical analyses were conducted with the software R, version 4.1.3 (120). Missing data for sociodemographic data is indicated in Appendix C, Table 1. Aside from those variables, for 55 participants, missing data included n=3 MIBS at T1, n=8 MIBS at T2, n=15 Bayley, n=3 HADS-A at T1, n=8 HADS-A at T2, n=3 EPDS at T1, and n=8 EPDS at T2, n=5 IBQ-R. For the purpose of analysis of the main outcomes, the missing data of main variables (the predictor and outcomes) was removed from the analysis since the missing values were not missing at random, preventing them from being imputed (121).

To test (cross-sectional and prospective) associations between maternal CB-PTSS and mother-infant bonding, we carried out statistical analyses without covariates (unadjusted model) and with covariates (adjusted model), as presented in Appendix C, Table 2 and Table 3. For the adjusted model, potential covariates for mother-infant bonding were infant temperament (negative and positive emotionality), depression symptoms, anxiety symptoms, history of trauma, and parity. Only covariates significantly associated with the outcomes were introduced in the adjusted models (see Appendix F, Supplementary Materials, Table 1).

To test (cross-sectional and prospective) associations between maternal CB-PTSS and infant development outcomes (cognitive, motor, and language), we conducted bivariate linear regressions for the unadjusted models and adjusted models to test the significance of potential covariates (depression, anxiety, sex of the infants, and Apgar score at 5 minutes) associated with cognitive, motor, and language development. Significant covariates were used in the adjusted model for multivariate regression analysis. In all analyses, p-values of <0.05 were considered statistically significant.

For mother-infant bonding outcomes, in the cross-sectional analysis at T1, two outliers were identified and removed from the data of 52 participants using Mahalanobis distance ($p<.001$) (122). Similarly, in the prospective analysis (PCL-5 at T1 and MIBS at T2), two outliers were excluded from the data of 47 participants. In the cross-sectional analysis at T2, one outlier was removed from same dataset. No outliers were identified for infant development outcomes.

5.1.3 Results

5.1.3.1 Associations of Maternal CB-PTSS and Mother-Infant Bonding

The analysis of mother-infant bonding outcomes is described in Appendix C, Table 2 and Table 3. In the unadjusted model at T1, significant cross-sectional positive associations were found: (1) between higher PCL-5 total score and higher MIBS total score ($p=0.000$, $B=0.152$, 95% CI 0.079–0.224, Cohen's $f2=0.121$); (2) between PCL-5 GS score and MIBS total score ($p=0.000$ $B=0.268$, 95% CI 0.155–0.381, Cohen's $f2=0.475$; and (3) between PCL-5 BRS score and MIBS total score ($p=0.037$ $B=0.151$, 95% CI 0.009–0.292, Cohen's $f2=0.095$). In the adjusted model (controlling for EPDS and HADS-A at T1), significant cross-sectional positive associations were found: (1) between PCL-5 total score and MIBS total score ($p=0.017$, $B=0.134$, 95% CI 0.025–0.243, Cohen's partial $f2=0.133$) and (2) between PCL-5

GS score and MIBS total score (p=0.002, B=0.306, 95% CI 0.117–0.496, Cohen's partial f2=0.230).

In the cross-sectional analysis at T2, we found a significant positive association between PCL-5 BRS score and MIBS total score (p=0.025, B=0.114, 95% CI 0.014–0.215, Cohen's f2=0.121). No significant covariates were identified, thus we did not have an adjusted model for cross-sectional analysis between PCL-5 and MIBS at T2. In the prospective analysis, in the unadjusted model, only a prospective significant positive association was found between PCL-5 total score and MIBS total score (p=0.043, B=0.064, 95% CI 0.002–0.127, Cohen's f2=0.371). No significant covariates were identified, thus we did not have an adjusted model for prospective analysis between PCL-5 and MIBS.

5.1.3.2 Associations of Maternal CB-PTSS and Infant Development Outcomes

In the prospective analysis shown in Appendix C, Table 4, for the unadjusted model, we found that higher BRS at T1 were associated with a higher infant cognitive subscale score of Bayley III at T2 (p=0.026, B=0.748, 95% CI 0.092–1.404). Cohen's f2 was 0.144, indicating a small-to-medium effect size (123). For the adjusted model as shown in Appendix C, Table 5, we identified EPDS at T1 as a significant covariate for motor development but did not find any significant associations in this adjusted model. For the cross-sectional associations between PCL-5 (total, GS, BRS scores) and infant development (cognitive, language, and motor) at T2, we did not find any significant associations. A significant covariate identified was EPDS at T2, but no significant results were found in this adjusted model.

5.1.4 Personal contribution

I contributed to the conception of the study idea. I was involved in data cleaning, preparation, and analysis, as well as in the interpretation of the results along with the statisticians. Additionally, I wrote the original manuscript and revised it based on suggestions from co-authors.

5.2 Study 2: Early mother-infant interactions within the context of childbirth-related posttraumatic stress symptoms

This study is currently under review in Journal of Affective Disorders in 2024 and the original submitted **article can be found in Appendix D.**

5.2.1 Aims

The purpose of this study was to investigate the differences of mother-infant interactions in the context of different symptom clusters of maternal CB-PTSS. We hypothesized that mother-infant interactions would be different between groups (i.e., BRS, GS, and NS).

5.2.2 Methods

5.2.2.1 Participants

To determine the differences in mother-infant interactions between groups in the context of CB-PTSS, we classified participants into three groups: BRS, GS, and NS based on maternal report on PTSD Checklist for DSM-5 (PCL-5) (see below on section 5.2.2.2 instruments for more detail). Medium-to-large effects were expected based on previous study (14). Hence, a total sample 75 dyads would be sufficient to detect a significant effect of $\eta 2$ = 11.8% with a power of 80%, while a total sample of 90 dyads would permit to detect effects larger than 10%. To ensure a sufficient sample size for potential attrition, to increase statistical power, and to enable subgroup analysis, a total sample size of at least 90 was targeted. The present

study consisted of two phases. In phase 1 (retrospective), we utilized data from the control group (n=38) of a RCT on the prevention of CB-PTSD following unplanned cesarean section (NCT 03576586) (25, 107). Phase 2 was conducted to achieve the required total sample size. In the end, we collected n=62 in phase 2, which altogether makes a total sample size of n=100 mother-infant dyads.

Inclusion criteria were mothers speaking French or English with term (gestational weeks ≥37) healthy infants, who gave written consent. Exclusion criteria were no sufficient French or English language skills to participate, current psychotic illness, intellectual disability, severe illness of mothers or infants, alcohol abuse or illegal drug use during pregnancy. The procedure detailed below only concerned phase 2, for a detailed explanation of the procedure in phase 1, please refer to its study protocol (107). Nevertheless, both phases followed the same procedure for data collection. The local ethics committee approved the studies for phases 1 (2017-02142) and 2 (2022-00716).

Hence, for phase 2, recruitment and data collection took place between August 2022 to September 2023. We distributed advertisements seeking participants in the development unit at a French-speaking Swiss University Hospital, day cares, clinics of gynecologists and pediatricians. Additionally, we posted advertisement online on the French-speaking Swiss University Hospital website and on social media platforms (e.g., Instagram, Facebook, LinkedIn) allowing us to reach more people. Eligible participants received further explanations about the research, including the purpose of the study, procedures, risks and benefits, and approximate duration of the study. They were informed that the participation in the study was entirely voluntary. Further, once they agreed to participate, they were required to sign a written informed consent. All mother-infant dyads would be eligible up to six months postpartum. After obtaining written informed consent, data collection was scheduled at approximately six months postpartum.

We asked participants to complete maternal self-report questionnaires online using the REDCap (124). About one week later, mothers and infants were invited to the University Hospital to film the interactions. The session took place in a single room equipped with two moveable cameras mounted on opposite walls. Mothers were instructed to play with their infants as they would at home using a standardized set of toys provided by the researchers. Free-play sessions were recorded for 15 minutes. In cases where participants (n=47) were not able to come to the hospital due to scheduling conflicts or transportation difficulties, appointments were scheduled at their homes, following the same procedure. To the best of my knowledge, to date, no studies have specifically addressed the differences between mother-infant interactions videotaped at home and those recorded in a hospital setting. Moreover, this procedure had been discussed with a co-author who is an expert in mother-infant interactions.

5.2.2.2 Instruments

Sociodemographic and obstetrical data were collected through maternal self-report questionnaire, as reported in Appendix D, Table 1. Maternal CB-PTSS was measured with PCL-5, as in Study 1. In Study 2, Cronbach's alpha for PCL-5 was 0.89, indicating a strong internal consistency. For groups classification, symptoms are counted when they are present as a score of two or higher (2). Based on participants' responses to the PCL-5, they were divided into three groups (NS, BRS, GS). Dyads were assigned to the BRS group if the mother scored two or higher on BRS-related items (items 1 through 8 and 10 to 11). Conversely, if her score was two or higher on GS-related items (items 9 and 12 through 20), the dyad was placed in the GS group. If none of the items scored two or higher, the dyad was classified into the NS group. In cases where mothers' total scores for both BRS and GS were equal, we prioritized assigning her and her infant to the BRS group. This was based on studies demonstrating that re-experiencing symptoms (BRS) were linked to less positive

infant outcomes, specifically in motor development (11), and that avoidance symptoms (BRS) were associated with lower parenting satisfaction (42).

Mother-infant interactions was measured with the Global Rating Scale (GRS), a parent-child interaction coding scheme (74). From the 15 minutes of filmed interactions, we selected segments spanning from minute three to minute six for coding. This duration of three minutes aligns with the methodology of previous studies (77, 125). The interactions were coded by three reliable coders who previously got trained and completed a reliability test. Interrater reliabilities of ≥ 0.79 were achieved for all the subscales of the GRS, indicating strong agreement among the raters. This coding scheme had been used by several studies looking into mother-child interactions in various clinical conditions (126-128). The standardized and validated coding scheme includes nine subscales which assess infant behaviors (two scales), maternal behaviors (five scales), and joint behaviors (two scales). Infant subscales include emotional tone and self-regulation. Emotional tone of infants refers to how content the infant is during interactions, while self-regulation measures how well infants regulate their emotional and physical responses to certain events during the interactions (74).

Maternal subscales include positive and negative expressed emotions, maternal coercions or intrusions, maternal emotional tone, and sensitivity (74). Maternal expressed emotions are comments from the mothers that could be positive, affectionate, complimentary, or negative and critical, directed at the infant.

To score these maternal expressed emotions, we transcribed and translated the interactions into French and/or English for mothers who did not speak either language during free-play (n=10). Despite participants in the study being fluent in English or French, they were instructed to engage in play as they normally would at home, to make the interactions as natural as possible, allowing them to use their native languages with their infants. Maternal coercions or intrusions refers to forceful positioning or guidance that cut across or disrupt the infant's activity. Maternal emotional tone pertains to the level of contentment displayed during interaction. Maternal sensitivity refers to how attuned the mother is to the infant's signals.

Joint subscales include general atmosphere and reciprocity during play. Reciprocity assesses whether there is turn-taking and sharing attention during interactions. General atmosphere refers to whether the mother and infant's overall contact is pleasant or disharmonious (discordant and conflictual). In total, we had nine subscales to assess mother-infant interactions. All subscales were coded on a 5-point rating scale, with higher scores indicating better outcomes (e.g., more sensitive, more self-regulated), except for positive and negative expressed emotions, and maternal coercions, which were measured as event counts. In the analysis, each subscale was analyzed separately.

Maternal depression and anxiety symptoms were measured as potential covariates as studies shown these often comorbid with CB-PTSS (27, 77, 129). Maternal depression and anxiety symptoms were measured with EPDS and HADS-A as in Study 1. In Study 2, Cronbach's alpha for EDPS was 0.85, indicating a strong internal consistency while Cronbach's alpha for HADS-A was 0.77, indicating a moderate level of internal consistency.

5.2.2.3 Statistical Analyses

5.2.3 Results

5.2.3.1 Descriptive statistics

A total 100 mother-infant dyads participated. Among these, 34 dyads were in NS group, 20 in BRS group, and 46 in GS group. The mean age of participants was 33.58 years (SD=4.19). Overall, 63 % (n=63) of mothers were Swiss and 80% (n=80) were married, cohabitated, or

were in a relationship. The majority of mothers (73%, n=73) in the study were well-educated, and multipara (61%, n=61). The number of mothers who had a vaginal birth or underwent unplanned cesarean section was the same. There were 51 female (51%) and 49 male (49%) infants. Further details on participant demographic information for each group is presented in Appendix D, Table 1.

We also examined the differences between groups. We found six variables (i.e., history of past trauma, EPDS, HADS-A, PCL-5, gestational weeks, APGAR score) were significantly different ($p<0.05$), as shown in Appendix D, Table 1. Appendix D, Table 2 presents a comprehensive overview of scores across various subscales of the GRS, including median values and interquartile ranges (IQR) in general and for each group (NS, BRS, GS).

5.2.3.2 Differences of mother-infant interactions between groups

We employed negative binomial regressions to analyze maternal positive expressed emotion and maternal coercions, as they were measured as event counts. Additionally, ordinal logistic regression analysis was conducted for assessing variables measured on a Likert scale, including maternal emotional tone, maternal sensitivity, infant emotional tone, infant self-regulation, general atmosphere, and reciprocity. The unadjusted model of negative binomial and ordinal logistic regression analysis indicated no significant group differences in any of the GRS subscales ($p<0.05$) during free-play mother-infant interactions, as presented in Appendix D, Table 3.

As some of the sociodemographic, obstetrical, and maternal health data (see Appendix D, Table 1) showed significant differences between groups, we added these six variables in the adjusted model. In Appendix D, Table 4, the adjusted model showed that the NS group had significantly lower maternal coercions compared to the BRS group (B=-1.46, p=0.01, 95%CI=-2.63, -0.36). Furthermore, the GS group showed higher reciprocity compared to the BRS group (B=1.21, p=0.03, 95%CI=0.05, 3.37). Finally, the sensitivity analysis showed the results of the adjusted analysis did not change depending on the phase of recruitment (data not shown).

5.2.4 Personal contribution

I contributed to the conception of the study and drafting the study protocol for ethics approval. I was highly involved in study coordination, particularly in participant recruitment, data collection, and data management. Moreover, I coordinated and supervised interns assisting with data collections. I conducted data analysis and interpretation with advice from a statistician. Furthermore, I drafted the original manuscript and revised it based on suggestions from co-authors.

5.3 Study 3: Mother-infant physiological and behavioral synchrony in the context of childbirth-related posttraumatic stress symptoms

This study is currently under review in the Journal of Affective Disorders and the original submitted **article can be found in Appendix E.**

5.3.1 Aims

This study investigated if there is physiological synchrony between mother-infant HRV during social interactions in the context of CB-PTSS at six months postpartum. We hypothesized there was mother-infant HRV synchrony and that HRV synchrony was different between CB-PTSS groups: non-symptomatic (NS), BRS, and GS (hypothesis 1). The second aim was to investigate the association between mother-infant physiological and behavioral synchrony.

We hypothesized there was association between mother-infant physiological and behavioral synchrony (hypothesis 2).

5.3.2 Methods

5.3.2.1 Participants

As in Study 2, this study was approved by the local ethics committee (2022-00716). Given that no study had yet investigated the mother-infant HRV synchrony in the context of CB-PTSS, the effect size could not be determined a priori. Comparable to a study investigating mother-infant HRV synchrony in the context of healthy dyads (84, 89, 100), we collected data from 86 mother-infant dyads. Data of 28 mother-infant dyads came from the control group of an RCT study (NCT 03576586) (107), as in Study 1 and Study 2. A further 58 dyads were recruited after that to have a large enough sample size. All data were collected at six months postpartum. We included French- and English-speaking mothers who gave birth to healthy infants, gestational age of 37 weeks or more, and gave written consent. Exclusion criteria were no sufficient French or English language skills to participate, current psychotic illness, intellectual disability, severe illness of mothers or infants, alcohol abuse, or illegal drug use during pregnancy.

At six months postpartum, participants were asked to complete online maternal self-report questionnaires using the REDCap software (124). The questionnaire assessed maternal CB-PTSS, medical, and sociodemographic data. One week or less after completing the online questionnaire, an appointment was made at the participant's home or at the university hospital, depending on the participant's availability. Mothers were asked to play with their infants as they would do at home for 15 minutes with a standardized set of toys provided by the researchers. Interactions were filmed and both mothers' and infants' heart rates were recorded using a Firstbeat Bodyguard 2 device (130).

5.3.2.2 Instruments

Maternal CB-PTSS were measured using the PCL-5 as in Study 1 and Study 2. Mother-infant dyads were grouped based on maternal reports on the PCL-5, following the grouping steps outlined in Study 2, detailed in section 5.2.2.2. HRV, as an indicated variable for physiological regulation, was measured with the ECG device, Firstbeat Bodyguard 2 (130). The Firstbeat Bodyguard 2 is a small device which can be attached to the mother's and infant's chest by two disponsible electrodes. Maternal and infant HRV was measured during the free-play for 15 minutes, with a mid-sequence (from minute three to minute six) selected for further analysis, as in Study 2. There were no restrictions on movements during recording. After recording, we extracted the data and processed it using R v4.3.0 (120).

Behavioral synchrony was operationalized as the reciprocity between the mother and her infant during filmed free-play interaction observed by trained coders using the GRS (74) which was part of procedures in Study 2. Reciprocity refers to the level of mutual interaction between mother and infant during play, including communication, joint orientation, cooperative coordination and turn taking (74). According to the manual, reciprocity is coded on a Likert scale from 1 (no reciprocity) to 5 (very much reciprocity).

5.3.2.3 Statistical Analyses

We first resampled the dyads' HRV raw signals during the three minutes' interaction into one-second window timeframes using HRV values average or interpolation when appropriate, to ensure even measures between mother-infant dyads. Out of the 86 dyads, six dyads with artefacts (i.e., abnormal HRV values) were excluded, leaving 80 dyads classified into three groups: non-symptomatic (27 dyads), birth-related symptoms (13 dyads), and general

symptoms (30 dyads) based on PCL-5. To test mother-infant physiological synchrony (hypothesis 1), we used cross-lagged correlations at the dyad level with a 20-second time-lag limit, to check whether any particular temporal pattern showed up across dyads. The cross-lagged correlation coefficients' distribution was calculated as the mean of the cross-lagged correlation coefficients for all dyads at each time-lag. Each dyad was classified as positive (mother and infant HRV were fluctuating in the same direction) or negative (mother and infant HRV were fluctuating in the opposite direction), depending on the sign of its correlation at time-lag 0. As averaging positive and negative correlation coefficients would have canceled out the resulting distribution and, consequently, hid some potential effects, we took the decision to treat the positively (40 dyads) and negatively (40 dyads) correlated dyads separately, similar to a previous study (21).

Linear mixed effect models identified autocorrelation in mother-infant HRV signals (autocorrelation measures the relationship between a variable's current value and its past values). The mlVAR R package (131) was used to obtain dyads temporal effects, estimated by calculating the regression coefficients obtained by predicting mother (respectively infant) HRV signals at time t from infant (respectively mother) HRV signals at time t-1 and t-2. To minimize the signals' autocorrelations, we approximated the dyads' HRV signals with Autoregressive Integrated Moving Average (ARIMA) models with one autoregressive and one moving average terms (84, 132). The cross-lagged correlations (with no time-lag) were computed, for each dyad, on ARIMA residuals. Positive and negative distributions were compared and differentiated from a null hypothesis of an average 0 correlation using Kolmogorov-Smirnov tests.

We also compared the HRV signals' cross-correlation (no time-lag) distributions between real and surrogate dyads. The surrogate dyads were made up by combining the HRV signals of a mother of a given dyad and a randomly chosen infant of another dyad. Kolmogorov-Smirnov tests were used to confirm that the mother-infant true dyads' cross-correlations distributions were not drawn from chance. Differences of mother-infant physiological synchrony between CB-PTSS groups were also tested using ANOVA type II and pairwise tests on estimated - marginal means with Tukey corrections to account for the unbalanced design of the PCL-5 groups.

Finally, ANOVA type II and pairwise tests on estimated marginal means with Tukey corrections were also used to test the relationship between the mother-infant behavioral and physiological regulation interaction in the context of CB-PTSS (hypothesis 2), using the interaction between the cross-correlation coefficients (time-lag 0) and the PCL-5 groups. All the analyses were done using R v4.3.0 running in RStudio v2023.06.0 build 421(120, 133). We used two-tailed significance, and $\alpha < .05$ for all statistical tests.

5.3.3 Results

5.3.3.1 Descriptive statistics

The mean age of mothers was 33.45 years (SD=4.15). The majority were married, cohabitating, or in relationships (84.71%, n=72), and 65.88% (n=56) were Swiss nationals. Additionally, 19.77% (n=17) were nulliparous, and 76.47% (n=65) had received university or applied science education. Regarding childbirth, half of the mothers (48.84%, n=42) had vaginal births. Furthermore, 51.16% (n=44) of the infants were female. The median maternal PCL-5 score was 7 (IQR=10). The median gestational week was 40 (IQR=2), with median APGAR score 10 (IQR=1), mean infants' weight of 3373.95 grams (SD=478.24). We had 16 dyads in the BRS group, 38 in the GS group, and 32 in the NS group. Further details on participant demographic information for each group is presented in Appendix F, Table 2.

5.3.3.2 Mother-infant physiological synchrony

The cross-lagged correlation coefficients' distribution graph (Appendix E, Figure 1) shows a correlation optimum for the positively and negatively correlated dyads, suggesting a synchrony between the mother and her infant HRV signals. The positively correlated dyads showed a maximum (r=0.146) at time-lag 2, indicating that, on average, the mothers' HRV signals were leading the infants' HRV signal by 2 seconds. The negatively correlated dyads showed a minimum (r=-0.155 at time-lag 0), indicating that on average, neither the mothers', nor the infants' HRV signals were leading or lagging.

Multi-level vector autoregression models were used to analyze the relationships between the mothers' and infants' HRV signals. The network temporal relationships showed that the mothers' and infants' HRV signals, for both positive and negative dyads, were mostly auto-correlated as shown in Appendix E, Table 1. There was a marginally significant positive effect (β=0.025, p=0.071) of the mothers' HRV signals at time-lag 1 on the infants' HRV signals for the positive dyads. There was a negative significant effect (β=-0.029, p=0.033) of the infants' HRV signal at time-lag 1 on the mothers' HRV signals for the negative dyads.

To eliminate the effects of the auto-correlated part of each signal, we fitted the dyads' HRV signals with Auto Regressive Integrated Moving Average (ARIMA) models, with one autoregressive term and one moving average term, and used the residual parts to compare corresponding cross-correlation coefficients' distributions, at time-lag 0, between positive and negative dyads (Appendix E, Figure 2). Kolmogorov-Smirnov tests showed that the positive and negative ARIMA residuals cross-lagged correlation coefficients' distributions were significantly different (D=1, p<0.001) and significantly different from a null hypothesis of an average 0 correlation (D=0.50, p<0.001 for the positive dyads, and D=0.50, p<0.001 for the negative dyads).

In the second set of analyses, we conducted a surrogate test to check whether the cross-correlation coefficients from empirical dyads came from a statistically similar distribution as coefficients from random pairings of individuals into dyads (21). To answer this question, for the positive and negative dyads' groups, separately, we randomly paired an infant from one dyad with a mother from another dyad and estimated the time-lag 0 cross-correlation coefficient (Appendix E, Figure 3). Results showed that the surrogate distribution was, as expected, centered at 0, indicating no correlation. The Kolmogorov-Smirnov tests revealed that empirical and surrogate distributions were not sampled from the same population for the positive dyads (D=0.58, p<0.001) nor the negative dyads (D=0.45, p<0.001), confirming that the mother-infant empirical dyads' cross-correlations' distributions were not drawn from chance.

5.3.3.3 Differences of mother-infant physiological synchrony between CB-PTSS groups

Type II ANOVA tests on ARIMA residuals cross-lagged correlation coefficients distributions per PCL-5 classification showed that, for the positive dyads (Appendix E, Figure 4a), there were no significant mean physiological regulation differences between the PCL-5 groups (F(2, 37) = 2.08, p=0.14). For the negative dyads (Appendix E, Figure 4b), there were no significant mean physiological regulation differences between the PCL-5 groups either (F(2, 37) = 0.89, p=0.42).

5.3.3.4 Mother-infant behavioral and physiological synchrony

We found no significant main effect for HRV synchrony (physiological synchrony) on reciprocity (behavioral synchrony), neither for the positive dyads (F(1, 33)=1.76, p=0.19), nor for the negative ones (F(1, 34)=0.06, p = 0.80). We found a significant main effect of the PCL-5 groups on reciprocity (F(2, 33)=3.58, p=0.04). For the positive dyads (Appendix E, Figure 5a), the estimated marginal mean for reciprocity was marginally higher for the GS group compared to the BRS group (estimated marginal mean difference = -0.81, p = .08) but not significantly higher compared to the non-symptomatic group (estimated marginal mean difference = -0.56, p=0.11). The reciprocity estimated marginal mean was not significantly different between the BRS group compared to the NS group (estimated marginal mean difference = -0.25, p=0.79). For the negative dyads (Appendix E, Figure 5b), we did not find any significant main effect of the PCL-5 groups on reciprocity (F(2, 34)=1.04, p=0.36). The interaction between the PCL-5 groups and the HRV was not significant, for both the positive and the negative groups.

5.3.4 Personal contribution

I contributed to the conception of the study, drafting the study protocol for the ethics approval and data collection (which was integrated with Study 2). I was responsible for study coordination, including the participant recruitment, data collection, and data management. Moreover, I coordinated with collaborators and the supervised interns assisting with data collection. With the exception from statistical analysis and results section, I drafted the original manuscript and revised it based on suggestions from co-authors.

6 General discussion and perspectives

6.1 Interpretation of findings

6.1.1 Mother-infant bonding, infant development, and CB-PTSS

We found that higher maternal CB-PTSS (i.e., total score, BRS, GS) were cross-sectionally associated with lower mother-infant bonding at six weeks postpartum. Adjusting for maternal postpartum depression and anxiety symptoms, cross-sectional associations at six weeks postpartum between maternal CB-PTSS (GS and total score) and mother-infant bonding were still significant. At six months postpartum, significant associations emerged between BRS and mother-infant bonding in the unadjusted model. Prospectively, we found associations between a total score of CB-PTSS at T1 and mother-infant bonding in the unadjusted model at T2. For infant development outcomes, we detected a prospective association between higher BRS and better cognitive infant development in the unadjusted model.

Our results showed that mothers with higher symptoms of maternal CB-PTSS had more difficulties in mother-infant bonding. These cross-sectional results at six weeks postpartum aligned with several previous studies that showed postpartum bonding is significantly associated with CB-PTSD (12, 13, 39-41, 57, 63, 64). However, compared to our study, previous studies had substantially larger sample sizes, for example, Handelzalts et al (39) included 504 mothers of infants aged 0-13 months, while Nakić Radoš et al (41) included 603 mothers of infants aged 1-12 months. Additionally, Parfitt and Ayers (63) included 152, consisting of 126 mothers and 26 fathers, measured at 1-24 months postpartum.

Handelzalts et al. (39) and Nakić Radoš et al. (41) found that BRS was not associated with mother-infant bonding but GS. Further, Nakić Radoš et al. explained that GS directly associated with bonding and indirectly influenced it through depressive symptoms (41). This is aligned with the finding of our study at six weeks postpartum that after controlling for

maternal anxiety and depression, only GS associated with mother-infant bonding. Moreover, a longitudinal study with 210 postpartum women found that GS at two months postpartum mediating the associations between adult attachment postpartum bonding at six months postpartum but not BRS (40). Unlike their approach, our research focused on the direct association between CB-PTSD and mother-infant bonding, without considering adult attachment styles, which could introduce bias in our study, given the association between adult attachment and mother-infant bonding (40).

Another longitudinal study of 356 mothers found a negative prospective association between maternal CB-PTSD symptoms at one month postpartum and mother-infant bonding at three months postpartum (12). However, that association was no longer significant after adjusting for anxiety and depression symptoms at one month postpartum. Further, they explained that anxiety and depression at one month mediated the association between maternal intrusion and hyperarousal symptom subscales and parental-infant bonding at three months postpartum (12). This, was also found in another study indicating that maternal postpartum depression mediated indirect relationship between CB-PTSS and mother–infant bonding (64).

Our study at six months postpartum showed similar results to some extent, though not entirely identical. In our study, after adjusting for maternal anxiety and depression, the association between CB-PTSS and mother-infant bonding were not significant either, except for BRS. It is important to note that the study by Stuijfzand et al. (12) addressed a limitation of our study by controlling for antenatal maternal mental health, given the known association between antenatal maternal mental health and mother-infant outcomes (58, 77, 134). Furthermore, it would be beneficial if future studies could measure bonding during pregnancy, as studies show that stronger antenatal bonding predicted stronger mother-infant bonding after childbirth (56, 135)

Moreover, the prospective association found between maternal CB-PTSS and lower mother-infant bonding, and the cross-sectional association between BRS and mother-infant bonding at six months postpartum in our study, are consistent with a previous study (13). For instance, Dekel et al. (13) observed lower attachment in CB-PTSD compared to non-childbirth PTSD and no CB-PTSD, although they used the term "attachment" instead of "bonding". Nevertheless, the instrument they used, the MAI, measured the same concept as bonding (110).

Our unexpected finding that infants of mothers with higher symptoms of BRS had better cognitive development is not consistent with previous studies that found either no association (14) or a negative association (11, 15). Noteworthy, these three studies did not test prospective associations between maternal CB-PTSS and infant development in infants younger than one-year-old and they did not differentiate between GS and BRS (11, 14, 15), which may partly explain the discrepancy of our findings with previous studies.

Alternatively, this unexpected result we observed might be attributed to limitations in statistical power, as our study had a small sample size, consisting of a total sample of 39 dyads in the analysis for infant development outcomes. Small sample sizes can increase the risk for type II errors where there is a higher chance of missing real effects. If this is the case, there may be no real significant relationship between these two variables, which is consistent with the study by Feeley et al., which also measured infant development at six months postpartum, although they tested the association cross-sectionally only (14). However, it is important to consider alternative explanations as well. For instance, traumatic childbirth may lead mothers to feel guilty about not being good enough as parents (136, 137). This could extend to feelings of inadequacy towards their infants (138), leading them to overcompensate and invest more in their infants, potentially resulting in better infant cognitive development (18, 139). In addition, we did not look into the role of fathers or other

co-parents. This might cause bias, as father/co-parent–child interactions or any regular paternal involvement may affect the development of the children (140, 141), especially the cognitive and psychological infant outcomes (140). Moreover, maternal distress, indicated by increased cortisol, may benefit child development depending on timing. For instance, one study found that elevated cortisol at 15 weeks gestation was linked to lower infant cognitive scores, while levels at 37 weeks correlated with improved cognitive development at 12 months, suggesting a potential role for cortisol in the maturation of fetal organ system (142).

6.1.2 Mother-infant interactions and CB-PTSS

The objective of this study was to explore the differences of mother-infant interactions between groups based on different maternal CB-PTSS clusters (BRS, GS, and NS) at six months postpartum. Our study demonstrated that mother-infant interactions (infant emotional tone, infant self-regulation, maternal emotional tone, maternal expressed emotion, maternal coercions, maternal sensitivity, general atmosphere, and reciprocity) at six months postpartum did not differ significantly between CB-PTSS groups. However, after adjusting for covariates (i.e., history of past trauma, maternal postpartum depression, maternal anxiety, CB-PTSS score, gestational weeks, APGAR score), we found that mothers of the BRS group engaged in more frequent coercions compared to the NS group and showed lower reciprocity in their interactions with their infants compared to the GS group.

Our finding regarding the maternal coercions/intrusions aligns with a longitudinal study by Ionio and Di Blasio (10) with 19 mother-infant dyads, which also found that mothers with more CB-PTSS at two months postpartum were more intrusive during interactions with their infants. The authors hypothesized that mothers with more symptoms were feeling more anxious and insecure when the attention of their infant was not on them, which may explain their increased intrusiveness, tendency to touch their infants more and to make more noise to re-focus their infant's attention onto them (10). Similarly, Muller-Nix et al. (79) and Forcada-Guex et al. (80) found that mothers with higher a CB-PTSS score tended to display more controlling behaviors at six months postpartum, showing "controlling a mother and compliant infant" interaction pattern.

Despite similar findings, there were differences between our study and the three studies mentioned in the previous paragraph. Ionio and Di Blasio (10) used a FFSF paradigm at three months, whereas our study used a free-play (normal social interaction) paradigm at six months, similar to studies by Muller-Nix et al. (79) and Forcada-Guex et al. (80). Moreover, we used a different instrument to code the interactions. Muller-Nix et al. (79) and Forcada-Guex et al. (80) used the CARE index, while our study used the GRS. It is also worth noting that Muller-Nix et al. (79) and Forcada-Guex et al. (80) included preterm infants, which was an exclusion criteria in our study. Nonetheless, despite these methodological disparities, our findings align with those of Ionio and Di Blasio (10), Muller-Nix et al. (79) and Forcada-Guex et al. (80), indicating the robustness of our results across different designs.

In addition, our findings suggest higher levels of reciprocity during mother-infant interactions in the GS group compared to the BRS group. This indicates that increased symptoms related to re-experiencing and avoidance in mothers are associated with less reciprocity during interactions, in contrast to those experiencing more symptoms related to negative cognition and hyperarousal. This could imply that mothers affected by re-experiencing symptoms might be distracted, potentially resulting in reduced attentiveness to their child's signals (32). Similarly, it could be suggested that mothers with more avoidance symptoms may not be able to pay full attention to their infant during the interaction and thus miss some important cues their infant sends. Indeed, a study reported that mothers with high CB-PTSS scores did not directly look at their infants' faces during play and reunion sessions during a FFSF paradigm and that their infants tended to look away during the still-episode, which might

contribute to less reciprocity during interactions (10). Nevertheless, these were two different paradigms (free-play and FFSF), and future research is thus needed to confirm our findings.

In contrast to previous studies reporting that a higher score of maternal CB-PTSS was associated with lower maternal sensitivity at six months postpartum (14, 79, 80), we did not find differences in maternal sensitivity between groups. Different study samples might contribute to this different finding. In a study by Feeley et al., the participants were mother-infant dyads whose infants had been hospitalized in the NICU (14), and for the studies by Muller-Nix et al. (79) and Forcada-Guex et al. (80), the participants included were mother-infant dyads with full-term and premature infants. Moreover, these studies did not control for maternal depression and anxiety, which are often comorbid with maternal CB-PTSS (3) and shown to be associated with less maternal sensitivity (143, 144).

However, Rousseau et al. (27) found similar results They indicated that more severe and persistent CB-PTSS were related to lower maternal sensitivity measured with Coding Interactive Behavior, even after controlling for maternal depression and anxiety (27). It is worth noting that their study involved infants who were younger (four months old) compared to ours (27). Additionally, they specifically measured not only the severity but also the stability of CB-PTSS across the first months postpartum (72h, 1 month, and 4 months postpartum), and found that one time point in their study, either 72h, 1 month, or 4 months postpartum also did not significantly associate with mother-infant interactions, including maternal sensitivity. Moreover, they found that maternal CB-PTSS was associated with infant avoidance of social gaze toward the mother during free-play (27), similar to the finding by Ionio and DiBlasio (10) which observed infants averting their gaze during the still-phase of FFSF. Although in Study 3, we did not specifically observe the infants' gaze, this might have contributed to the lower score of reciprocity in the BRS group.

Finally, it is important to note that our study, along with all those mentioned above, did not measure maternal antenatal mental health, which might bias the results. Only one study in the literature measured maternal antenatal mental health. In this study, they did not find any associations between maternal CB-PTSS and mother-infant interactions (77). Instead, it was prenatal anxiety measured in late pregnancy that associated with mother-infant interactions (i.e., maternal unresponsiveness, infant passivity) (77).

6.1.3 Synchrony (physiological and behavioral) and CB-PTSS

This observational study aimed to firstly explore the synchrony between the mother's and infant's physiological regulation during free-play interactions at six months postpartum, in the context of CB-PTSS. Secondly, it investigated if mother-infant physiological synchrony during interactions was associated with mother-infant behavioral synchrony.

Our results indicated there was significant physiological (i.e., HRV) synchrony between mothers and their infants. This finding is in line with a study by Feldman et al. (84) in healthy dyads who found mothers' HRV and infants' HRV were coordinated to each other. We observed in the positive dyads (i.e., mother and infant HRV were fluctuating in the same direction) a significant effect of the mothers' HRV signal at time-lag 1 on the infants' HRV signal. In negative dyads (i.e., mother and infant HRV were fluctuating in the opposite direction), we found a significant effect of the infants' HRV signal at time-lag 1 on the mothers' HRV signal was found. This corresponds to findings reported by Feldman et al. (84) that identified a bidirectional influence, where infants' HRV leads to an increase or decrease of mothers' HRV and vice versa. Mother-infant HRV synchrony was also confirmed by our finding that showed cross-correlations' distributions of mother-own infant dyads and mother-other infant dyads differed significantly (which was also observed by Feldman et al. (84)). Therefore, our findings suggest that in the context of CB-PTSS, mother-infant physiological synchrony exhibits similarities to that observed in healthy dyads (84).

In terms of maternal CB-PTSS, both in positive dyads and negative dyads, physiological synchrony was not significantly different between BRS, GS, and the NS groups. Although none of the studies so far focused on maternal CB-PTSS, previous research on maternal mental health symptoms, such as maternal depression and maternal anxiety, had yielded mixed results (89, 100, 101). In groups of mother-infant dyads with maternal depression and without depression, no difference in their heart rate synchrony was observed (100). However, another study on dyads with maternal history of major depressive disorder found that dyads with no history of depression showed physiological synchrony, while dyads with a history of major depressive disorder showed discordance (101). Meanwhile, in a study on mother-infant dyads with maternal anxiety, higher physiological synchrony was found in dyads with more anxious mothers compared to less anxious mothers, suggesting that more anxious mothers lack the ability to buffer stress and to downregulate their arousal when the overall arousal level of the dyad is high (89). Thus, higher physiological synchrony in dyads is not always associated with better maternal mental health.

We observed no significant association between physiological and behavioral synchrony in either positive or negative dyads. As no study has investigated dyads' physiological synchrony in the context of CB-PTSS so far, direct comparisons with previous literature are not possible. Further studies are required to confirm our findings and delve into the mechanisms underlying the association (or lack of) between physiological synchrony and behavioral synchrony.

6.2 Strength and limitations of the thesis

6.2.1 Study 1

Study 1 is the first longitudinal study to identify the associations between CB-PTSS and infant development in infants under one-year-old whose mothers underwent unplanned cesarean sections. We assessed infant development using validated and standardized clinical assessments. Moreover, we controlled for maternal and infant covariates in the analysis. However, some limitations must be pointed out. Our findings cannot be generalized to other modes of childbirth than mothers underwent unplanned cesarean sections with term infants. Aside from that, the generalizability of our findings may be limited because a sizable proportion of our participants were single mothers. According to one study, unmarried women had higher bonding with their infants compared to married women (145). The self-report questionnaire used to measure maternal CB-PTSS may not be as robust as an objective, clinical assessment to examine CB-PTSD. Nonetheless, PCL-5 is an appropriate instrument, as it is valid, reliable, and widely used in both research and clinical practice. In addition, the Cronbach alpha for the MIBS to measure bonding in our participants was borderline and results should therefore be interpreted with caution. Replication of our results with a larger sample size, taking into consideration the involvement of the father or other co-parents is recommended.

6.2.2 Study 2

One of the innovative aspects of Study 2 is that we grouped dyads based on their CB-PTSD symptom classifications (i.e., NS, BRS, and GS) instead of using the total score calculation or classification based on certain cut-off points as in previous studies (10, 14, 77, 79). This provides a new and more detailed insight into the quality of mother-infant interactions in terms of symptom clusters. However, a potential bias may arise in the classification of dyads for mothers with equal BRS and GS total scores when assigning them to the BRS group, as this has not been thoroughly investigated in previous research. Our decision was influenced by studies suggesting that BRS symptoms often have more pronounced effects, such as being associated with lower parenting satisfaction (although this study focused on war-

related PTSD in fathers) and less positive infant outcomes (11, 42). However, another study found that BRS was not associated with bonding but rather associated with GS (41).

Moreover, our study included a larger sample size compared to previous studies on mother-infant interactions in the context of CB-PTSS (10, 14). Nonetheless, this study has some limitations. We did not extensively measure maternal prenatal mental health, which might influence the results, as prenatal anxiety symptoms might be associated with quality of mother-infant interactions (77). Moreover, we did not take into account any measure of the co-parents. The use of a cross-sectional design limited the exploration of how consistent these findings are regarding mother-infant interactions between groups over time. Even though this design was sufficient for our study aim, future studies would benefit from inclusion of longitudinal studies to provide additional insights into the long-term implications of maternal CB-PTSS on mother-infant interactions, as one study suggested that the persistence of CB-PTSS across different timepoints is associated with mother-infant interactions (27).

6.2.3 Study 3

Study 3 is the first to investigate the association between mother-infant's HRV and reciprocity in the context of maternal CB-PTSS during free-play interactions, adding to the literature new knowledge regarding the mother-infant physiological and behavioral synchrony in the context of maternal CB-PTSS. In addition, we applied comprehensive extensive analysis techniques to confirm our findings. While our study provides novel insights, it is not without limitations. Our sample size was relatively small, although it is comparable to previous studies looking into mother-infant physiological synchrony (84, 89, 100). The cross-sectional design did not allow us to understand the potential changes of this association between maternal CB-PTSS and mother-infant HRV and behavioral synchrony over time. The generalizability of our findings is limited to mother-infant dyads with term infants. In addition, the lacking association between physiological and behavioral synchrony might have been biased due to individual differences in the capacity for physiological regulation, such as vagal suppression that interacts with dyads' behavioral synchrony (21, 43).

6.3 Implications

6.3.1 Clinical implications

The findings of this thesis hold several important implications for nursing practice, particularly in providing care for mothers and infants during the postpartum period. The postpartum period is a vulnerable time for many women, characterized by significant physiological, psychological, and social changes (146). During this period, nurses and midwives play a crucial role in providing essential support and guidance to parents. They facilitate visits of hospitalized infants, and community nurses collaborate with midwives to conduct home visits, offering crucial care guidance (147). Moreover, nurses and midwives are responsible for assessing, identifying, and addressing parents' needs, including mental health support, and for collaborating with other healthcare professionals for necessary treatments (147). The findings from these PhD studies showing significant consequences of maternal CB-PTSS on mother-infant bonding and quality of interactions, particularly in maternal coercion and reciprocity, highlight the importance of routine screening of maternal CB-PTSS for early detection and intervention, allowing nurses to provide timely support and referrals to appropriate mental health resources to improve outcomes for both mothers and infants.

By understanding the consequences of CB-PTSS, nurses can better identify the need for professional advocacy, which not only encompasses screening and comprehensive assessments but also includes education, empowerment, individualized care plans, supportive counseling, promoting bonding through skin-to-skin and kangaroo care

immediately after childbirth, advocating for resources and policy changes, as well as conducting community outreach and education. Nurses can explain the impact of CB-PTSS on bonding, interactions, synchrony, and infant development that have been explored in this thesis, reassuring mothers that experiencing symptoms does not mean they are incapable of forming a strong bond and interacting well with their infants. Nurses can collaborate with mental health professionals to develop individualized care plans for mothers experiencing CB-PTSS, incorporating various evidence-based interventions. These interventions include a single-session visuospatial task procedure (25), trauma-focused cognitive behavior therapy (CBT), eye movement desensitization and reprocessing, expressive writing interventions, psychological counseling, mother-infant dyadic focused strategies, and psychological or social support (3, 148). However, further research on interventions, particularly nursing intervention, is still needed (149), especially to address specific symptom presentations (i.e., BRS, GS), given our finding of Study 2 that mothers experiencing BRS might be more susceptible to be coercive and less reciprocal during interactions.

Another important role of nurses is health promotion. In several countries such as the United States and Ireland, nurses, especially public health nurses, play a crucial role in health promotion, during the initial postnatal visit, offering comprehensive care encompassing physical, psychological, and social well-being for both mothers, infants, and families (147). In Switzerland the roles for public health nurses seem to vary based on the Canton. In Canton of Vaud and other French speaking parts of Switzerland, the follow up of infants is carried out by Early Childhood Nurses (*infirmier·ère·s petite enfance*) where nurses undertake home visits upon parental request, providing families with an opportunity to consult on health-related issues and parenting concerns (150).

Home visits are beneficial for providing insights into understanding the parent-child relationship (151), improving the duration of breastfeeding, and increasing mothers' emotional and verbal responsiveness, particularly among socially disadvantaged families (152). Moreover, a meta-analysis study of 111 articles found that various parenting interventions (not specific to nurses) can improve not only parenting knowledge but also parenting practices and parent–child interactions (113). Moreover, nurse interventions focused on behavioral coaching have been shown to improve the quality of the maternal-infant relationship in mothers with postpartum depression (153). However, another study conducted with socially disadvantaged participants at risk found that parenting education and support programs, while beneficial in improving some outcomes such as breastfeeding, did not significantly result in better parent-child interaction and child outcomes (152). Further research is needed to examine the effectiveness of these types of nursing interventions in the context of maternal CB-PTSS.

Aside from home visits, nurses can engage with local communities to raise awareness about maternal mental health issues and the significance of healthy mother-infant relationships (154). This may involve organizing workshops, seminars, collaborating with community organizations and healthcare providers, and providing informational materials and training sessions to improve understanding and support for maternal mental health initiatives. Moreover, nurses can also facilitate support groups for mothers with CB-PTSS to connect with others who may be facing similar challenges and receive encouragement and validation (155). Participating in a support group can help mothers feel less alone in their struggles and provide them with self-care, practical advice, and coping strategies for managing their symptoms and improving their interactions with their infants (155).

However, nurses may lack the knowledge and skills, due to insufficient training, to address all aspects of mental health (151, 154). This includes assessing parent-child relationships and opening a discussion with women on more sensitive or complex issues that may include CB-PTSS, and providing information to women (151, 154). This deficit could hinder their ability to confidently assess perinatal mental health issues that might obstacle their role in

provision of emotional care and support (156). Findings from this PhD thesis could contribute to enrich nurses' understanding of the consequences of maternal mental health issues on mother-infant relationships and infant development but future research aimed at enhancing training in this area, skills to assess mother-infant relationships and address sensitive or complex issues, is still needed to effectively implement the knowledge gained from the findings of these thesis projects into practice. Moreover, further training for nursing staff working with mothers with mental health difficulties might be necessary, to address negative perceptions toward mothers and provide optimal care (157).

6.3.2 Theoretical implications of the thesis and research perspectives

This thesis provides useful insights into the associations between maternal CB-PTSS and various outcomes, including bonding, infant development, mother-infant interactions, and mother-infant behavioral and physiological synchrony. Our findings partly align with the middle range theory of traumatic childbirth (32) and the intergenerational transmission of stress and trauma framework (8). Particularly the observation on negative consequences of traumatic childbirth in mother-infant bonding, and mother-infant interactions, specifically less reciprocity and more maternal coercion, but not in physiological synchrony and infant development.

I will begin by discussing the implications of the study's findings on the middle-range theory of traumatic childbirth (Framework 1) (32), followed by an exploration of their implications for the intergenerational transmission of stress- and trauma-related consequences (Framework 2) (8). Study 1's findings indicated alignment with Framework 1, where a higher CB-PTSS score was associated with poorer mother-infant bonding. However, while the middle-range theory describes negative consequences of traumatic birth on mother-infant bonding and mother-infant interaction, it lacks specificity for further explanation on each aspect. Study 1 showed an association between CB-PTSS total score and poorer mother-infant bonding, but the negative consequences of maternal CB-PTSS were not consistent for mother-infant interaction outcomes. In Study 2, only dyads in the BRS group that were more likely to exhibit maternal coercion and less reciprocity. Notably, not all interactions aspects were disrupted. For example, there were no significant differences between CB-PTSS groups in maternal sensitivity and infant self-regulation. This challenges the assertion within the framework that impaired mother-infant interactions may serve as a primary indicator of a traumatic birth. Moreover, this suggests a need to extend the framework to include the two-factor symptoms of CB-PTSS (i.e., BRS, GS) and specify which symptom factors and subscales of interactions are associated.

Additionally, it is crucial to note that this PhD thesis focuses on CB-PTSS, not CB-PTSD diagnosis. In Framework 1, CB-PTSD and CB-PTSS were mentioned simultaneously without addressing their individual consequences. Considering the observed negative consequences of CB-PTSS on mother-infant bonding and interaction quality, it can be hypothesized that dyads with maternal CB-PTSD may face even more severe outcomes.

Regarding Study 3's findings, synchrony (behavioral and physiological) was not explicitly addressed in the framework. Extending or modifying Framework 1 to incorporate detailed synchrony aspects, measured behaviorally and physiologically, in mother-infant interactions could enhance understanding. Although CB-PTSS is generally linked to poorer mother-infant bonding and BRS negatively affects interaction quality, no CB-PTSS groups affected physiological synchrony. By integrating physiological measures, understanding of the consequences of maternal CB-PTSS on mother-infant relationships can be more comprehensive.

Turning to Framework 2, the intergenerational transmission of stress and trauma framework (8) focuses on stress and trauma broadly rather than specifically on maternal CB-PTSS, yet

it remains applicable. This framework explained that offspring of stress- or trauma-exposed parents may face physical, behavioral, and cognitive problems through three mechanisms as mentioned in section 3.2. However, in Study 1, no significant association was found between infant development outcomes and CB-PTSS in the adjusted model. Moreover, in the unadjusted model, BRS related to better infant cognitive development. This result contradicts the framework, possibly because the PhD studies exclusively focused on the postpartum period, thereby omitting examination of other mechanisms outlined in the framework—such as parental gamete quality and the intrauterine environment—which were not addressed in this thesis. This omission may have limited the comprehensiveness of the analysis conducted, as it did not consider potentially significant factors that could influence the infant development outcomes.

This framework could be enhanced by incorporating the symptoms factors of PTSD to determine if these different factors affect outcomes in the same way. Furthermore, while Study 2 found an association between BRS and maternal behavior during interactions—specifically, maternal coercion and reduced reciprocity—indicating the impact of traumatic childbirth, this effect was not observed at the physiological level in Study 3. Moreover, my PhD studies focused solely on the association between maternal CB-PTSS and infant development, without exploring the link between mother-infant interaction and synchrony with infant development. It is unknown if disruptions in mother-infant interactions due to maternal CB-PTSS are associated with infant development outcomes. Future research, possibly through longitudinal designs, could shed light on this aspect by considering parental mental health during both the prenatal and antenatal periods.

Results from Study 1 indicated that mothers experiencing a higher score of CB-PTSS associated with poorer mother-infant bonding. Specifically, a higher score of GS at six weeks postpartum was associated with decreased mother-infant bonding at six months postpartum. Adjusting for maternal depression and anxiety, association between GS and poorer mother-infant bonding was only observed cross-sectionally at six weeks postpartum. Symptoms of negative cognition and moods, which is a part of GS, closely resemble those seen in depression (2). Research indicates that mothers experiencing symptoms of postpartum depression often develop distorted perceptions of themselves and their parenting abilities (158). These negative self-perceptions can contribute to a negative view of their infants, as they may project their own negative feelings onto their infants thus lead to lower infant-bonding (158-160).

However, as in Study 2, regarding the outcome of mother-infant interactions, mothers in BRS group were the ones more susceptible to experiencing lower quality of mother-infant interactions due to increased maternal coercion and decreased reciprocity, as opposed to mothers in GS groups. It is possible that mothers in GS might perceive their bonding to their infants as more negative while it is not necessarily observed in their interactions. Therefore, future research should investigate the relationships between subjective measurements (i.e., maternal reports of mother-infant bonding) and objective measures (i.e., observed mother-infant interactions) to observe possible discrepancies. Moreover, it is important also for future research to control for comprehensive preexisting mental health status, including the presence of chronic trauma experienced by mothers. Chronic trauma exposure can lower mothers' capacity for empathy, potentially affecting their relationships with their infants (58, 161).

Referring back to the intergenerational transmission of stress and trauma framework, one of the mechanisms through which the stress and trauma experienced by mothers are transmitted to infants is through the early mother-infant interactions, which later affect development of the offspring. In Study 2, a lower quality of mother-infant interactions (less reciprocity, more coercions) was observed in BRS group. However, in Study 1, no negative

outcomes in infant development were observed after adjusting for maternal postpartum depression.

It is plausible that the non-significant associations found between maternal CB-PTSS and infant development observed in Study 1, may be attributed to the timing of the measurement of infant development. It is conceivable that at six months postpartum, the influence of maternal CB-PTSS on infant development may not yet be apparent, thus, explaining the lack of significant negative association in Study 1. This suggestion is supported by a previous research, which also found no significant association at six months postpartum (14). Additionally, as Study 1 only focused on the postpartum period, which represents the third mechanism of intergenerational transmission of stress and trauma framework, the future studies could benefit from considering the role of stress and trauma experienced by parents before (prenatal) and during pregnancy.

Moreover, in Study 1, the unadjusted model of maternal CB-PTSS and infant development showed infants of mothers with higher symptoms of BRS had better cognitive development, which contradicts the middle range theory of traumatic childbirth (32) and intergenerational transmission of stress and trauma framework (8). There was another study that reported a similar contradictory finding, although it did not specifically focus on maternal CB-PTSS but rather on maternal mental health issues (i.e., prenatal anxiety, nonspecific stress, and depressive symptoms). They found that maternal mental health problems were associated with more advanced motor development in children at two years old and that maternal anxiety and depression were also significantly and positively associated with mental development (134). This uncommon finding is also supported by another study, which suggests that moderate psychosocial distress may slightly improve motor development, and certain aspects of language acquisition (162). These findings highlight the complex association between maternal CB-PTDD and child development, suggesting that maternal stress and trauma may, under certain circumstances, contribute to beneficial outcomes for child development.

Furthermore, another study explained that the timing of exposure of stress, indicated by cortisol level, was predictive of the outcomes of infant development where elevated levels of maternal cortisol early in gestation, at 15 weeks, were associated with a lower score of infant cognitive development (142). On the other hand, increased maternal cortisol levels during the late stages of gestation, at 37 weeks, correlated with improved scores in infant cognitive development at 12 months. This suggests that elevated cortisol levels are beneficial and needed for the maturation of fetal organ systems (142). Therefore, to investigate the association between maternal CB-PTSS and infant development more accurately, future studies could benefit from controlling for prenatal mental health for both parents, maternal mental health during pregnancy, and objective measures indicated by cortisol in different time points. Moreover, controlling for father/co-parent involvement, as it is positively associated with better cognitive and psychological infant outcomes would be beneficial (140).

The measures of quality of mother-infant relationships can also be measured objectively through physiological synchrony (163). Study 3 demonstrates the presence of physiological synchrony between mothers and infants, irrespective of maternal CB-PTSS status. This suggests that while CB-PTSS may influence maternal-infant interaction as observed in Study 2, it may not necessarily disrupt physiological synchrony between mothers and infants. This might also suggest that the relationship between maternal CB-PTSS and mother-infant physiological synchrony may be more complex, and that future a study controlling for individual physiological regulation (e.g., vagal tone) is needed (21, 43). The second outcome of Study 3 showed the lack of association between physiological and behavioral synchrony. At six months postpartum, infants are still developing social interactions (20), so their behavioral responses during play interactions might be less consistent or predictable. It is plausible that physiological synchrony may show some more stability than behavioral

synchrony. Moreover, behavioral synchrony may be influenced by factors such as infants' temperament and culture (125, 163). Further research aimed at understanding the mechanisms linking physiological and behavioral synchrony needs to take these factors into account.

Future studies should adopt prospective, longitudinal studies to understand the causal relationship of CB-PTSS and mother-infant relationships (i.e., interactions, physiological synchrony). Moreover, research should consider the representativeness of study samples, as Study 1 only included mothers who underwent caesarean C-section, and all three studies only included mothers and infants from the French-speaking part of Switzerland. It may also be beneficial to conduct similar studies in developing countries to enhance the generalizability of the findings. Moreover, future research could potentially explore the effectiveness of culturally tailored interventions in addressing the unique needs of diverse populations affected by maternal CB-PTSS, as recognizing the importance of cultural competence in perinatal mental health care provision is crucial (125, 164).

In addition, future studies should also include co-parents, as they may play important roles in the outcomes of parent-infant relationships and infant development, as previously mentioned, regular paternal involvement leads to better cognitive and psychological outcomes in infants (140, 165). Furthermore, an effective coparenting relationship has been shown to significantly enhance maternal mental well-being, as demonstrated in a study conducted three months postpartum (166). This study specifically examined maternal postpartum depression, showing a correlation between EPDS scores and the extent of fathers' involvement in child-rearing activities on their days off (166). Interestingly, while increased father involvement during days off was associated with reduced maternal depression at three months postpartum, this effect was not observed at one month postpartum (166).

Takeishi et al. assumed different findings at one month and three months postpartum may attributed to the evolving nature of childcare needs (166). Initially, childcare primarily consists of breastfeeding, but by three months postpartum, fathers can engage more actively in activities such as playing with their infant, thereby reducing some maternal burden, facilitating physical and psychological recovery through activities like napping or leisure (166). Consequently, fostering a supportive coparenting dynamic and encouraging father or co-parent involvement can benefit maternal mental health and infant outcomes (140, 165, 166). Despite the positive outcomes associated with fathers or other co-parents' involvement, research including them is limited. For instance, in a meta-analysis study examining 111 articles, only one study measuring paternal outcomes, underscoring the limited scope of research in this area (113). Therefore, more future research is needed to explore fathers or other co-parents' involvement in mother-infant outcomes, particularly in the context of maternal CB-PTSS. Overall, all theoretical implications discussed in this chapter emphasize the complexity of mother-infant relationships and infant development in the context of maternal CB-PTSS and highlight the need for multidimensional approaches to understanding and supporting mothers experiencing CB-PTSS and their families.

7 General conclusion

This general aim of this thesis was to gain an understanding of the consequences of CB-PTSS on mother-infant relationships and infant development at six months postpartum. Study 1 found maternal CB-PTSS after mothers underwent unplanned cesarean sections were associated with negative mother-infant bonding outcomes to some extent, while also indicating better infant cognitive development in the unadjusted model.

Moreover, findings in Study 2 indicate that maternal CB-PTSS specifically related to birth-related symptoms (re-experiencing and avoidance) are associated with a higher frequency of maternal coercions and lower reciprocity during interactions with their infants at six months postpartum compared to mothers exhibiting no symptoms or experiencing general symptoms (negative cognitions and mood, and hyperarousal). Interventions aimed at tackling birth-related symptoms should be prioritized (compared to general symptoms when the resources are limited) to improve their interactions with their infants, making them less coercive and fostering improved reciprocity. However, our results also suggest that mothers experiencing these symptoms might feel reassured, as other aspects of interactions (i.e., maternal sensitivity, emotional tone, infant self-regulation) did not differ significantly between mothers with and without symptoms. Therefore, mothers could improve their interactions with their infants without excessive concern about potentially putting their infants at risk due to the consequences of the CB-PTSS they experience. Finally, in Study 3, although we did not find differences in physiological synchrony between CB-PTSS groups and observed no association between behavioral and physiological synchrony, our findings suggest there was mother-infant physiological synchrony.

In conclusion, while this thesis offers valuable insights, its limitations include a cross-sectional design and the absence of co-parents in the analysis. Therefore, further studies should include the role of co-parents as a covariate. Additionally, the use of longitudinal design would be beneficial to understand the causal relationship between CB-PTSS and both the mother-infant relationship and infant development over time. Moreover, additional studies are needed to enhance training and assist nurses in implementing knowledge gained from research findings into practice.

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9 Appendices

9.1 Appendix A

9.1.1 Search strategies and literature synthesis

Question originale (formulaire demande)	1. To compare observed mother-infant interactions between three groups (full symptoms, partial symptoms, non-symptoms) in the context of maternal CB-PTSD at 6 months postpartum. 2. To compare mother-infant bonding between groups in the context of CB-PTSD at 6 weeks and 6 months postpartum. 3. To investigate the relationships between CB-PTSD symptoms at 6 weeks and 6 months postpartum and infant development at 6 months postpartum. 4. To explore the relationship between maternal physiological regulation and infant physiological regulation at 6 months postpartum. 5. To investigate the differences between groups in terms of mother-infant physiological regulation at 6 months postpartum in the context of maternal CB-PTSD at 6 months postpartum. 6. To investigate relationships between mother-infant's behavioral regulation and physiological regulation at 6 months postpartum.
Question reformulée (si nécessaire)	*What is the association between CB-PTSD/postpartum depression and mother-infant interaction, mother-infant bonding, infant development, mother or infant physiological regulation, mother or infant behavioral regulation*

PICO

[P]opulation / Problem	[I]ntervention / Exposure	[C]omparison	[O]utcomes
Childbirth	CB-PTSD or postpartum depression		mother-infant interaction mother-infant bonding infant development mother or infant physiological regulation mother or infant behavioral regulation

Concepts retenus	Childbirth PTSD	Outcomes
Termes libres synonymes, termes apparentés (Recherche dans le titre et abstract)	((trauma* OR posttraumatic OR peritraumatic OR stress OR distress OR PTSD OR PTSS OR psychosis OR psychoses OR psychotrauma* OR "mental health" OR "postpartum depression*" OR "post partum depression*") ADJ3 (Childbirth OR Postpartum OR "post partum" OR Birth OR Labor OR Labour OR Parturition OR postnatal OR perinatal)) ((PTSD OR posttrauma* OR trauma*) ADJ1 (mother* OR maternal)) (depress* ADJ3 (Childbirth OR Postpartum OR "post partum"	((child OR children OR childs OR infant* OR newborn* OR baby OR babies OR motor) ADJ1 develop*) ((mother* OR maternal* OR child* OR newborn* OR infant* OR dyad OR dyads) ADJ8 (attachement OR bonding OR bond OR relationship* OR interaction* OR regulat* OR synchron* OR "heart rate*" OR "cardiac rhythm*" OR "hearth rhythm*" OR "heart beat*" OR reciproc* OR coordinat*))

	OR Birth OR Labor OR Labour OR Parturition OR postnatal OR perinatal)).ti.	
Descripteur(s) MeSH (Medline)	Stress Disorders, Post-Traumatic/ Stress Disorders, Traumatic, Acute/ Stress Disorders, Traumatic/ Psychological Trauma/ Stress, Psychological/ Depression, Postpartum/ AND exp Labor, Obstetric/ exp Parturition/ Delivery, Obstetric/	Object Attachment/ exp Child Development/ Mother-Child Relations/ Heart Rate/ Respiratory Sinus Arrhythmia/ Adaptation, Physiological/ Reactive Attachment Disorder/
Descripteur(s) PsycInfo	exp posttraumatic stress disorder/ posttraumatic stress/ "stress and trauma related disorders"/ acute stress disorder/ trauma/ emotional trauma/ psychological stress/ postpartum depression/ AND birth/ exp "labor (childbirth)"/	attachment behavior/ object relations/ childhood development/ motor development/ physical development/ psychological development/ psychomotor development/ mother child relations/ exp heart rate/ attachment disorders/

Stratégies de recherche proposées

1. Medline Ovid ALL

Ovid MEDLINE(R) ALL 1946 to May 10, 2022
Strategy with syntax to copy/paste into **Medline**
(((Stress Disorders, Post-Traumatic/ OR Stress Disorders, Traumatic, Acute/ OR Stress Disorders, Traumatic/ OR Psychological Trauma/ OR Stress, Psychological/ OR Depression, Postpartum/) AND (exp Labor, Obstetric/ OR exp Parturition/ OR exp Delivery, Obstetric/)) OR ((((trauma* OR posttraumatic OR peritraumatic OR stress OR distress OR PTSD OR PTSS OR psychosis OR psychoses OR psychotrauma* OR "mental health" OR "postpartum depression*" OR "post partum depression*") ADJ3 (Childbirth OR Postpartum OR "post partum" OR Birth OR Labor OR Labour OR Parturition OR postnatal OR perinatal)) OR ((PTSD OR posttrauma* OR trauma*) ADJ1 (mother* OR maternal))).ab,ti,kf. OR (depress* ADJ3 (Childbirth OR Postpartum OR "post partum" OR Birth OR Labor OR Labour OR Parturition OR postnatal OR perinatal)).ti.)) AND (Object Attachment/ OR exp Child Development/ OR Mother-Child Relations/ OR Heart Rate/ OR Respiratory Sinus Arrhythmia/ OR Adaptation, Physiological/ OR Reactive Attachment Disorder/ OR (((child OR children OR childs OR infant* OR newborn* OR baby OR babies OR motor) ADJ1 develop*) OR ((mother* OR maternal* OR child* OR newborn* OR infant* OR dyad OR dyads) ADJ8 (attachement OR bonding OR bond OR relationship* OR interaction* OR regulat* OR synchron* OR "heart rate*" OR "cardiac rhythm*" OR "hearth rhythm*" OR "heart beat*" OR reciproc* OR coordinat*))).ab,ti,kf.) NOT (exp animals/ not humans.sh.)

2448	**références trouvées le**	**11 mai 2022**
Commentaire(s) :		

2. APA PsycInfo

APA PsycInfo 1806 to May Week 1 2022
Strategy with syntax to copy/paste into **APA PsycInfo**
(((exp posttraumatic stress disorder/ OR posttraumatic stress/ OR "stress and trauma related disorders"/ OR acute stress disorder/ OR trauma/ OR emotional trauma/ OR psychological stress/ OR postpartum depression/) AND (birth/ or exp "labor (childbirth)"/)) OR ((((trauma* OR posttraumatic OR peritraumatic OR stress OR distress OR PTSD OR PTSS OR psychosis OR psychoses OR psychotrauma* OR "mental health" OR "postpartum depression*" OR "post partum depression*") ADJ3 (Childbirth OR Postpartum OR "post partum" OR Birth OR Labor OR Labour OR Parturition OR postnatal OR perinatal)) OR ((PTSD OR posttrauma* OR trauma*) ADJ1 (mother* OR maternal))).mp. OR (depress* ADJ3 (Childbirth OR Postpartum OR "post partum" OR Birth OR Labor OR Labour OR Parturition OR postnatal OR perinatal)).ti.)) AND (attachment behavior/ OR object relations/ OR childhood development/ OR motor development/ OR physical development/ OR psychological development/ OR psychomotor development/ OR mother child relations/ OR exp heart rate/ OR attachment disorders/ OR (((child OR children OR childs OR infant* OR newborn* OR baby OR babies OR motor) ADJ1 develop*) OR ((mother* OR maternal* OR child* OR newborn* OR infant* OR dyad OR dyads) ADJ8 (attachement OR bonding OR bond OR relationship* OR interaction* OR regulat* OR synchron* OR "heart rate*" OR "cardiac rhythm*" OR "hearth rhythm*" OR "heart beat*" OR reciproc* OR coordinat*))).mp.) NOT (animal not human).po.

2793	**références trouvées le**	**11 mai 2022**
Commentaire(s) :	Limit : https://ww2.rch.org.au/library/searchtips.php	

3. PTSDPubs (ProQuest)

Strategy with syntax to copy/paste into PTSDPubs
(NOFT(((trauma* OR posttraumatic OR peritraumatic OR stress OR distress OR PTSD OR PTSS OR psychosis OR psychoses OR psychotrauma* OR "mental health" OR "postpartum depression*" OR "post partum depression*") NEAR/2 (Childbirth OR Postpartum OR "post partum" OR Birth OR Labor OR Labour OR Parturition OR postnatal OR perinatal)) OR ((PTSD OR posttrauma* OR trauma*) NEAR/0 (mother* OR maternal))) OR TI(depress* NEAR/2 (Childbirth OR Postpartum OR "post partum" OR Birth OR Labor OR Labour OR Parturition OR postnatal OR perinatal))) AND NOFT(((child OR children OR childs OR infant* OR newborn* OR baby OR babies OR motor) NEAR/0 develop*) OR ((mother* OR maternal* OR child* OR newborn* OR infant* OR dyad OR dyads) NEAR/7 (attachement OR bonding OR bond OR relationship* OR interaction* OR regulat* OR synchron* OR "heart rate*" OR "cardiac rhythm*" OR "hearth rhythm*" OR "heart beat*" OR reciproc* OR coordinat*)))

145	**références trouvées le**	**11 mai 2022**
Commentaire(s) :		

Results

Base de données	Date de la recherche	Nombre de références avant dédoublonnage	Nombre de références après dédoublonnage
Medline Ovid ALL	11 mai 2022	2448	2436
APA PsycInfo	11 mai 2022	2793	1706
ProQuest PTSD Pubs	11 mai 2022	145	32
TOTAL		**5386**	**4174**

9.1.2Summary table of literature review related to CB-PTSS and various outcomes

Mother-infant bonding outcomes and CB-PTSS				
Years - Authors	Country	Purpose	Study design (N)	Summary points
2008 - Davies J, Slade P, Wright I, Stewart P.	UK	To explore whether CB-PTSD are associated with mothers' early perceptions of their infant	Cross-sectional (211)	Mothers meeting full or partial criteria of CB-PTSD postpartum perceived their attachment relationships to be significantly less optimal and reported more negative maternal representations in terms of their infants being less warm and more invasive measured at six weeks.
2009 - Parfitt, Y.M., & Ayers, S.	UK	To examine the potential effects of PTSD symptoms following childbirth on the couple's relationships and parent-baby bond.	Cross-sectional (152, 126 women and 26 men)	CB-PTSD and depression were correlated with the couple's relationship and parent-baby bond. CB-PTSD symptoms had a direct effect on the bonding. Depression mediated effect of PTSD on the couple's relationship. Measured at 1-24 months postpartum.
2016 - Williams, C. Patricia Taylor, E. Schwannauer, M.	UK	To investigate the relationships between parenting experiences, metacognition, postnatal symptoms of posttraumatic stress disorder and depression and perceptions of the mother–infant bonding, confirming and extending upon metacognitive and mentalization theories.	Cross-sectional (502)	Involved mothers with infant who was under 12 months of age. CB-PTSS did not independently predict perceptions of the mother–infant bonding. Instead, depression mediated relationship between PTS and the mother–infant bond measured with MPAS.
2018 - S. Hairston, I., E. Handelzalts, J., Assis, C. and Kovo, M	Israel	Examine how mothers' attachment styles correlate with maternal bonding difficulties, using postpartum depression and CB-PTSS as possible mediation effect.	Cross-sectional (114)	CB-PTSS mediated the link between mothers' avoidant attachment style and lower mother-infant bonding measured with PBQ (i.e., greater rejection of infant and anger toward infant) at 4-12 weeks postpartum.
2019 - Handelzalts, J. E., Hairston, I. S., Muzik, M., Matatyahu Tahar, A., & Levy, S.	Israel	Investigate the association between personality factor (i.e., vulnerability (Neuroticism) and resilience (Dispositional Optimism) with bonding, using postpartum depression and CB-PTSD as possible mediators.	Cross-sectional (504)	Total score of CB-PTSS did not mediate the association between personality factors (vulnerability and resilience) and mother-infant bonding, the symptom cluster of GS was found to mediate this association. In contrast, the BRS cluster only predicted fewer bonding difficulties during the 0–13 months postpartum period.

2019 - Dekel, S., Thiel, F., Dishy, G., & Ashenfarb, A. L.	USA	To investigate if PP-PTSD symptoms limit maternal attachment more than non-childbirth PTSD.	Cross-sectional (685)	Attachment was lower in CB-PTSD than in non-childbirth PTSD and no CB-PTSD. CB-PTSD predicted less maternal attachment within the past 6 months. This study used the term “attachment” instead of “bonding”.
2020 - Stuijfzand, S., Garthus-Niegel, S., & Horsch, A.	Switzerland	To investigate the prospective relationship between parental PTSD-CB symptoms at 1 month postpartum and perceived parent-infant bonding at 3 months postpartum.	Prospective (488, 356 mothers and 132 fathers	Maternal PTSD-CB symptoms at 1 month postpartum were found to be negatively prospectively associated with mother-infant bonding at 3 months postpartum. Effect disappeared after adjusting for psychological distress at 1 month postpartum.
2020 - Nakić Radoš, Matijaš, M., Anđelinović, M., Čartolovni, A., & Ayers, S.	Croatia	To examine the relationship between PTSD symptoms, depressive symptoms, and mother-infant bonding.	Cross-sectional (603)	Birth-related PTSD symptoms did not have any effect on bonding or depressive symptoms. General PTSD symptoms had a direct effect on bonding and an indirect effect on bonding via depressive symptoms. Measured at 1-12 months postpartum.
2021 - Handelzalts, J. E., Levy, S., Molmen-Lichter, M., Ayers, S., Krissi, H., Wiznitzer, A., & Peled, Y.	Israel	To examine the relationship between adult attachment styles, postpartum psychopathology and the mother-infant bonding.	Prospective (210)	Avoidant attachment had indirect effects on bonding measured at six months postpartum through GS of CB-PTSS measured at two months postpartum and postpartum depression. Anxious attachment also had indirect effects on bonding through general PTSD symptoms. Birth-related PTSD symptoms were not associated with bonding.
Infant development outcomes and CB-PTSS				
Years - Authors	Country	Purpose	Study design (N)	Summary points
2011 - Feeley, N., Zelkowitz, P., Cormier, C., Charbonneau, L., Lacroix, A., & Papageorgiou, A.	USA	To examine how mother's PTSD symptoms are related to mother and infant characteristics and how those are associated with quality of mothers' interaction with their infant, and infant development.	Cross-sectional (21)	How ill the infant was during the NICU hospitalization was related to mothers' PTSD symptoms. Maternal CB-PTSD did not significantly associated with infant development measured at six months postpartum.
2014 - Parfitt, Y., Pike, A., & Ayers, S	UK	To examine whether parental mental health, parent–infant relationship, infant characteristics and couple’s relationship were directly or indirectly associated with the infant’s cognitive, language or	Prospective (42)	Maternal CB-PTSD measured at approximately 5 months postpartum was moderately associated with child poorer cognitive outcomes but was not significantly associated with language or motor scores measured at 17 months postpartum (16-20

		motor development.		months).
2017 - Garthus-Niegel, S., Ayers, S., Martini, J., von Soest, T., & Eberhard-Gran, M	Norway	To examine the impact of maternal postpartum post-traumatic stress disorder (PTSD) symptoms on child development.	Prospective (1472)	PTSD symptoms following childbirth at 8 weeks had greater negative outcomes on social development at 2 years of age for boys compared to girls. Infant development was measured based on maternal report using Ages & Stages Questionnaire.
Mother-infant interactions and CB-PTSS				
Years - Authors	Country	Purpose	Study design (N)	Summary points
2004 - Muller-Nix C, Forcada-Guex M, Pierrehumbert B, Jaunin L, Borghini A, Ansermet F.	Switzerland	To examine the relationship between mother-infant interaction over time, infant perinatal risk factors (i.e., prematurity), and maternal perinatal recollected traumatic experience.	Prospective (72, 47 preterm and 25 full-term)	Mothers of high-risk infants (i.e., gestational age less than 34 weeks), as well as mothers that had experienced traumatic stress in the perinatal period, were less sensitive and more controlling at 6 months. The interactional behavior of the preterm infant was different (i.e., infants more passive) from that of the full-term infant at 18 months of age and was correlated with maternal traumatic stress but not with perinatal risk factors.
2011 - Forcada-Guex M, Borghini A, Pierrehumbert B, Ansermet F, Muller-Nix C.	Switzerland	To examine the relationship between maternal posttraumatic stress, maternal attachment representations of the infant and mother–infant dyadic interactions.	Retrospective (72, 47 preterm and 25 full-term)	Full-term mothers were more likely to follow a “Cooperative” dyadic pattern of interaction (measured at 6 months of infant-corrected age) measured with CARE index. Preterm mothers with high CB-PTSS (measured at 18 months of infant-corrected age) were more likely to follow a “Controlling” dyadic pattern of interaction. In contrast, preterm mothers with low CB-PTSS were more likely to fall into a “heterogeneous” group (i.e., unresponsive, controlling) of patterns of dyadic interaction.
2011 - Feeley, N., Zelkowitz, P., Cormier, C., Charbonneau, L., Lacroix, A., & Papageorgiou, A.	USA	To examine how mother's PTSD symptoms are related to mother and infant characteristics and how those are associated with quality of mothers' interaction with their infant, and infant development.	Cross-sectional (21)	Mothers who reported more PTSD symptoms were observed to be less sensitive and less effective at structuring interactions with their infant at six months postpartum.
2013 - Ionio, C., & Di Blasio, P.	Italy	To investigate whether postpartum stress symptoms may affect mother–child relations	Prospective (19)	Maternal CB-PTSS measured at two days and two months postpartum were associated with child crying and disorganized during the play

				phase measured at 3 months postpartum. During the still face phase, the child tends to look away.
2013 - Parfitt, Y., Pike, A., & Ayers, S.	UK	To examine the effect of fathers' and mothers' pre and postnatal mental health on mother–infant and father–infant interactions.	Prospective (44 mothers and 40 fathers)	CB-PTSS measured at 3 months postpartum did not associate significantly with mother-infant interactions at 3 months postpartum but rather only prenatal anxiety measured in late pregnancy associates with mother-infant interactions.
2023 - Rousseau, S., Feldman, T., Shlomi Polachek, I., & Frenkel, T. I.	Israel	To examine the impact of CB-PTSS in early postpartum period on disruption in maternal behavior and infant social-engagement, controlling for comorbid postpartum internalizing symptoms.	Cross-sectional (192)	Mothers with CB-PTSS (measured at 3-day, 1-month, and 4-month postpartum) exhibited less sensitivity in interactions with their infants at four months postpartum.

9.2 Appendix B (approval from ethics committee of Vaud)

COMMISSION CANTONALE
D'ÉTHIQUE DE LA RECHERCHE
SUR L'ÊTRE HUMAIN
CER-VD
Av. de Chailly 23
1012 Lausanne

Pre Antje Horsch
UNIL - IUFRS - CHUV Bureau
-01/159
SV-A Secteur Vennes
Route de la Corniche 10
1010 Lausanne

Lausanne, le 21/06/2022
Réf. SG/ne/ac

Décision de la Commission cantonale (VD) d'éthique de la recherche sur l'être humain (CER-VD)

Project-ID	2022-00716
Titre du projet	Mother-infant relationships and infant development within the context of maternal childbirth-related posttraumatic stress disorder symptoms
Travail de master/de thèse de	Devita, Sella
Direction du projet	Pre Antje Horsch
Promoteur	CHUV - Pre Antje Horsch
Centres	Pre Antje Horsch, UNIL - IUFRS - CHUV, Lausanne

Décision

☒ Autorisation accordée
☐ Autorisation avec charges
☐ En l'état, l'autorisation ne peut pas être accordée
☐ Autorisation non accordée
☐ Non entrée en matière

Remarque : Merci de bien séparer la case à cocher pour l'accord d'être recontacté du consentement pour l'étude.

Classification

☒ Projet de recherche au sens de l'ORH — Catégorie : A
☒ recherche sur des personnes
☐ réutilisation du matériel biologique ou des données personnelles liées à la santé
☐ sur des personnes décédées
☐ sur des embryons et des fœtus
☐ avec rayonnements ionisants

Annexes

Obligations du requérant (promoteur ou direction du projet) :

Soumission de documents : les documents modifiés et les nouveaux documents relatifs à l'étude/au projet de recherche sont soumis via le dossier existant. Les documents qui ne sont plus valides sont effacés et remplacés par les nouveaux. Les documents révisés doivent être soumis une fois en mode « suivi des modifications » et une fois en mode « modifications acceptées » (« track changes » et « clean »). Les documents d'information et de consentement ainsi que le protocole doivent être transmis dans un format permettant la recherche (PDF navigable) ou scannés avec une fonction OCR (Optical Character Recognition). Le cas échéant, les documents révisés sont également mis à disposition des autorités compétentes pour approbation.
Remarque: La commission d'éthique compétente examine, dans le cadre du processus d'autorisation, les feuilles d'information et déclarations de consentement dans une des langues officielles suisses: allemand, français ou italien. La commission d'éthique ne fait qu'accuser réception des feuilles d'information et déclarations de consentement écrites dans d'autres langues. Le promoteur ou la direction du projet est responsable de la traduction correcte des documents.
Obligations d'annonce : Les obligations d'annonce (p.ex d'évènements indésirables, d'interruption d'étude) et de soumission pour autorisation des modifications essentielles obligatoires s'appliquent (Ordonnances). Le rapport final est à remettre à la commission d'éthique compétente dans un délai d'une année à compter de la fin ou de l'arrêt de l'étude.
Devoir d'enregistrement : Le promoteur d'un essai clinique doit procéder à l'enregistrement dans un registre primaire reconnu par l'OMS ou dans le registre de la bibliothèque médicale nationale des EtatsUnis d'Amérique (clinicaltrials.gov) puis indiquer le numéro de l'étude sur le portail BASEC. Le transfert des données vers le Swiss National Clinical Trials Portal (SNCTP) est effectué automatiquement suite à l'autorisation de l'étude par la commission d'éthique, sous réserve de l'accord du requérant. Les données relatives à l'essai clinique figurant sur les deux registres sont accessibles au public. Swissethics publie également sur son site des informations sur chaque étude ayant reçu une autorisation, à l'exception des essais cliniques de phase I.

Signification des décisions possibles

Autorisation accordée : L'étude peut commencer selon le plan de recherche accepté. Elle doit être menée dans le cadre des dispositions légales en vigueur. D'autres obligations d'autorisation (Swissmedic/OFSP) doivent être respectées.
Autorisation avec charges : L'étude peut commencer selon le plan de recherche accepté. Elle doit être menée dans le cadre des dispositions légales en vigueur. Les charges doivent être remplies dans un délai de 30 jours. Les documents modifiés seront réévalués en procédure présidentielle. D'autres obligations d'autorisation (Swissmedic/ OFSP) doivent être respectées.
En l'état, l'autorisation ne peut pas être accordée : L'étude ne peut pas commencer. Prière de répondre point par point aux conditions de la commission d'éthique et de nous faire parvenir les documents révisés avec les modifications apparentes et la mention de la date de la nouvelle version.
Autorisation non accordée : L'étude ne peut pas commencer dans sa forme actuelle. Une nouvelle soumission reste possible.
Non entrée en matière : Justification, voir ci-dessus, par exemple la commission d'éthique n'est pas juridiquement compétente pour accorder une autorisation ou l'étude ne nécessite pas d'autorisation.

Liste des documents soumis

Pre Antje Horsch, UNIL - IUFRS - CHUV, Lausanne		
nom du fichier	date du fichier	version
1. Cover Letter		
20220407-cover-letter.docx	07/04/2022	
20220509-2022-00716-form-rep-220426-vs-sd-ah.docx	26/04/2022	
20220518-cover-letter-ah.docx	26/04/2022	
2. Synopsis of the study plan		
20220407-synopsis-vs-sd.docx	09/03/2022	1
20220524-synopsis-clean.docx	26/04/2022	2
20220524-synopsis-bayley.docx	26/04/2022	2
3. Participant information sheet and informed consent (ICF)		
20220407-informed-consent-en-vs-sd.docx	09/03/2022	1
20220517-informed-consent-en-vs-ah-clean.docx	26/04/2022	2
20220517-informed-consent-en-vs-ah.docx	26/04/2022	2
20220523-informed-consent-fr-sd-clean.docx	26/04/2022	2
20220523-informed-consent-fr-sd.docx	26/04/2022	2
20220409-informed-consent-fr-vs-sd.docx	09/03/2022	1
4. Study plan (protocol), signed and dated		
20220408-sella-protocol-vs-sd2-ah-modbpr-1.docx	09/03/2022	1
signature-20220524105009517.pdf	26/04/2022	2
20220524-sella-protocol-bayley-ah.docx	26/04/2022	2
20220524-protocol-clean.docx	26/04/2022	2
5. CRF (Case Report Form)		
20220409-metronome-crf-vs.xlsx	09/03/2022	1
20220426-metronome-crf.xlsx	26/04/2022	2
6. Investigator's CV, dated		

horsch-cv-b.pdf	06/03/2022	

11. Other documents handed over to study participants

flyer-revised-en-2-cs.pdf	09/03/2022	1
20220518-en-1.pdf	26/04/2022	2
20220524-fr-1.pdf	26/04/2022	2
flyer-revised-fr-cs.pdf	09/03/2022	1

12. Details on nature and scope/value of compensation for participants

There is no compensation for the participation in this study

14. Information on secure handling of biological material and personal data, and in particular on the storage thereof

see doc/cat: **4**, page/ref: **15**

9.3 Appendix C (study 1)

Journal of Reproductive and Infant Psychology

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Maternal childbirth-related posttraumatic stress symptoms, bonding, and infant development: a prospective study

Sella Devita, Camille Deforges, Myriam Bickle-Graz, Jean-François Tolsa, Vania Sandoz & Antje Horsch

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JOURNAL OF REPRODUCTIVE AND INFANT PSYCHOLOGY
https://doi.org/10.1080/02646838.2023.2261057

Maternal childbirth-related posttraumatic stress symptoms, bonding, and infant development: a prospective study

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ABSTRACT

Background: Childbirth-related posttraumatic stress symptoms (CB-PTSS) including general symptoms (GS, i.e., mainly negative cognitions and mood and hyperarousal symptoms) and birth- related symptoms (BRS, i.e., mostly re-experiencing and avoidance symptoms) may disrupt mother-infant bonding and infant development. This study investigated prospective and cross-sectional associations between maternal CB-PTSS and mother-infant bonding or infant development (language, motor, and cognitive). **Method:** We analysed secondary data of the control group of a randomised control trial (NCT 03576586) with full-term French- speaking mother-infant dyads (n = 55). Maternal CB-PTSS and mother-infant bonding were assessed via questionnaires at six weeks (T1) and six months (T2) postpartum: PTSD Checklist for DSM-5 (PCL-5) and Mother-Infant Bonding Scale (MIBS). Infant development was assessed with the Bayley Scales of Infant Development at T2. Sociodemographic and medical data were collected from questionnaires and medical records. Bivariate and multivariate regression were used.
Results: Maternal total CB-PTSS score at T1 was associated with poorer bonding at T2 in the unadjusted model (B = 0.064, p = 0.043). In the adjusted model, cross-sectional associations were found at T1 between a higher total CB-PTSS score and poorer bonding (B = 0.134, p = 0.017) and between higher GS and poorer bonding (B = 0.306, p = 0.002). Higher BRS at T1 was associated with better infant cognitive development at T2 in the unadjusted model (B = 0.748, p = 0.026).
Conclusions: Results suggest that CB-PTSS were associated with mother-infant bonding difficulties, while CB-PTSS were not significantly associated with infant development. Additional studies are needed to increase our understanding of the intergenerational consequences of perinatal trauma.

ARTICLE HISTORY

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KEYWORDS

Infant development; mother- infant bonding; traumatic childbirth; PTSD; postpartum; Bayley

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/02646838.2023.2261057

Introduction

Up to 30–45% of women report perceiving birth as traumatic (Alcorn et al., 2010; Creedy et al., 2000; Soet et al., 2003). Childbirth may be classified as a traumatic event when the mother perceived it as a life threat for herself and/or her infant according to the stressor criteria of the Diagnostic and Statistical Manual of Mental Disorders − 5th Ed (DSM-5) (American Psychiatric Association, 2013). A traumatic childbirth may lead to childbirth- related posttraumatic stress disorder (CB-PTSD). This mental health disorder consists of four symptom clusters, namely re-experiencing, avoidance, negative cognition and mood, and hyperarousal (American Psychiatric Association, 2013). CB-PTSD has similar symptoms as general PTSD. Although childbirth could trigger PTSD that existed prior to childbirth, related to a previous traumatic event, such as sexual violence, CB-PTSD specifically refers to the traumatic experience of childbirth itself, with symptoms developing after experiencing a traumatic birth (Heyne et al., 2022).

However, in contrast to general PTSD, CB-PTSD symptoms can be divided into general symptoms (GS) and birth-related symptoms (BRS), which is why some authors have argued that CB-PTSD should be acknowledged as a sub-type of PTSD (Horesh et al., 2021). The two symptoms clusters (GS and BRS) of CB-PTSD were identified through exploratory factor analysis and were replicated in several studies across different countries (Ayers et al., 2018; Bayrı Bingöl et al., 2020; Handelzalts et al., 2018; Nakić Radoš et al., 2020; Sandoz et al., 2022). GS mostly contain symptom criteria of hyperarousal, negative cognitions, and mood, (Ayers et al., 2018; Sandoz et al., 2022; Weathers et al., 2013) while BRS mainly include criteria of intrusions and avoidance (Ayers et al., 2018; Sandoz et al., 2022; Weathers et al., 2013).

The prevalence of maternal CB-PTSD was reported to be 4.7% and approximately 12.3% of mothers have significant levels of childbirth-related posttraumatic stress symptoms (CB-PTSS) but without fulfilling diagnostic criteria (Heyne et al., 2022). These prevalence rates can depend on the mode of childbirth, e.g. in one cohort study, 27.3% of mothers reported CB-PTSS after emergency C-sections compared to 18.8% after vaginal birth (Schobinger et al., 2020). With approximately 701 million births worldwide from 2015 to 2020, more than 86 million women and their families might be affected by CB- PTSS every year (United Nations, 2019). Evidence suggests maternal CB-PTSS may have negative consequences for the whole family. For example, at one month postpartum, maternal CB-PTSS was associated with a lower rate and shorter duration of breastfeeding (Cook et al., 2018; Garthus-Niegel et al., 2018; Ayers et al., 2018). This may carry negative consequences, as breastfeeding has been associated with several positive developmental outcomes in infants (i.e., brain development, language skills, and motor development) (Grace et al., 2016; Herba et al., 2013; Whitehouse et al., 2011). Associations between breastfeeding and increased maternal sensitivity or enhanced attachment security were also reported (Tharner et al., 2012).

Moreover, CB-PTSS negatively affected mothers' relationships with their partner and their plan for pregnancy in the future to avoid another traumatic birth (Beck & Beck, 2015). CB-PTSS has a negative impact on couple relationship satisfaction, which is mediated by postpartum depression symptoms (Garthus-Niegel et al., 2018). The quality of the couple's relationship plays a pivotal role in their parenting, thereby influencing the child's attachment to their parents (Coln et al., 2013). This attachment, indeed, has profound implications for the child's mental well-being and overall development trajectory (Coln et al., 2013; Sroufe, 2005).

CB-PTSS can also negatively affect mother-infant bonding (Dekel et al., 2019; Stuijfzand et al., 2020), although some studies found maternal CB-PTSS was not associated with mother-infant bonding (Handelzalts et al., 2021; Nakić; Radoš et al., 2020). When investigating further the associations between GS or BRS and mother-infant bonding, GS indirectly affected mother-infant bonding negatively via maternal depressive symptoms (Nakić Radoš et al., 2020). These inconsistent results might be attributed to differences in methodology, age group, and instruments used. For example, the study by Nakić Radoš et al. (2020) included infants ranging in age from one to 12 months and was done cross- sectionally, while the study by Dekel et al. (2019), even though also with a cross-sectional design, only included infants aged up to 6 months. Difficulties in mother-infant bonding can lead to challenges in the mother-infant relationship and may negatively impact infant development, including aspects such as brain development, emotional well-being, and behaviour (Brockington, 2004; Brockington et al., 2006)

In the long term, CB-PTSS might also have negative consequences on child development (Feeley et al., 2011; Garthus-Niegel et al., 2017; Parfitt et al., 2014). To the best of our knowledge, three studies investigated the associations between maternal CB-PTSS and child development, with mixed results (Feeley et al., 2011; Garthus-Niegel et al., 2017; Parfitt et al., 2014) and with only one study exploring infant development at six months (Feeley et al., 2011). When measured prospectively, CB-PTSS assessed at eight weeks and five months postpartum was associated with poorer negative social development outcomes at 24 months postpartum, especially for boys (Garthus-Niegel et al., 2017), and lower cognitive outcomes at 17 months postpartum (Parfitt et al., 2014), respectively. However, in a cross-sectional analysis, maternal CB-PTSS was not associated with infant development at six months postpartum (Feeley et al., 2011). Differences in the methodology of these studies (i.e., use of various self-report questionnaires, distinct time points of data collection, and different sample sizes) might contribute to these mixed results. In the study by Garthus-Niegel et al. (2017), a maternal self-report questionnaire was used to measure child development at two years, while Feeley et al. (2011) and Parfitt et al. (2014) used Bayley Scales of Infant Development III (i.e.,

a clinician-administered standardised observational assessment) to measure child development at six months and 17 months, respectively. Moreover, participants in the study by Feeley et al. were very low birthweight infants who had been hospitalised in a neonatal intensive care unit (Feeley et al., 2011). Given the inconsistent results concerning the associations between CB-PTSS and mother- infant bonding and infant development, as well as the recent introduction of the GS and BRS distinction, more research is needed.

This study aimed to investigate the prospective and cross-sectional associations between 1) maternal CB-PTSS and mother-infant bonding and 2) maternal CB-PTSS and infant development. We hypothesised higher maternal CB-PTSS would be associated with poorer mother-infant bonding and a lower score of infant development. Furthermore, we explored the role of covariates on mother-infant bonding and on infant development. For the bonding outcome, the potential covariates we identified by a systematic search of the literature were depression symptoms (Suetsugu et al., 2020; Taylor et al., 2005; Tichelman et al., 2019), anxiety symptoms (Davies et al., 2008; Handelzalts et al., 2021; Stuijfzand et al., 2020), parity (Yoshida et al., 2020), infant temperament (Nolvi et al., 2016; Takács et al., 2020), and history of trauma (Seng et al., 2013). For infant temperament, based on previous research (Nolvi et al., 2016; Takács et al., 2020), we considered positive temperament and negative temperament as potential covariates for bonding. For infant developmental outcome, the potential covariates we identified from the literature were maternal symptoms of depression (Aoyagi & Tsuchiya, 2019; Garthus-Niegel et al., 2017; Parfitt et al., 2014), maternal symptoms of anxiety (Parfitt et al., 2014), sex of the infants (Garthus-Niegel et al., 2017), and Apgar score at 5 minutes, which is a predictor to measure the infant development in the long term (Moster et al., 2002; Razaz et al., 2019).

Methods

Participants

This study is a secondary analysis of data from the control group of a randomised controlled trial, the Swiss TrAumatic biRth Trial (START) (NCT 03576586) (Sandoz et al., 2019). START aimed to test the efficacy of an early brief behavioural intervention including a visuospatial task to prevent maternal CB-PTSS. Recruitment occurred at two Swiss university hospitals at ≤ six hours postpartum. In our study, two time points were used: six weeks postpartum (T1), and six months postpartum (T2). At the time of study conception, no comparable previous research existed that would have allowed us to compute the sample size based on their effect size. However, we aimed for our sample size to be comparable to other relevant studies (Feeley et al., 2011; Parfitt et al., 2014). The current study included 55 mother-infant dyads from the START control group. To be eligible for the current study, mothers had to be ≥18 years old who had an emergency caesarean section as well as a fluent French speaking level, and had to have given birth to a healthy infant at ≥37 weeks of gestation who was aged approximately six months at the time of assessment. Figure 1 illustrates the participants' flowchart, while Table 1 shows descriptive data of sociodemographic and medical data of the mothers and infants.

Procedure

Participants completed online maternal-report questionnaires (using the Research Electronic Data Capture (REDCap) software) at T1 measuring maternal CB-PTSS, mother- infant bonding, and covariates (depression and anxiety symptoms, infant temperament, history of trauma). At T2, participants were contacted again through a phone call, a message, or e-mail to fill in the same online questionnaires and to arrange an appointment to assess infant development. Infant development at T2 was assessed at the hospital via a clinician-administered standardised observational assessment. Sociodemographic data were assessed by maternal-report questionnaire and medical data were extracted from hospital records.

Instruments

Maternal CB-PTSS was measured with the PTSD Checklist for DSM-5 (Weathers et al., 2013), a 20-item self-report questionnaire assessing PTSS over the past month. The traumatic event referred to childbirth. Participants responded using a Likert scale from

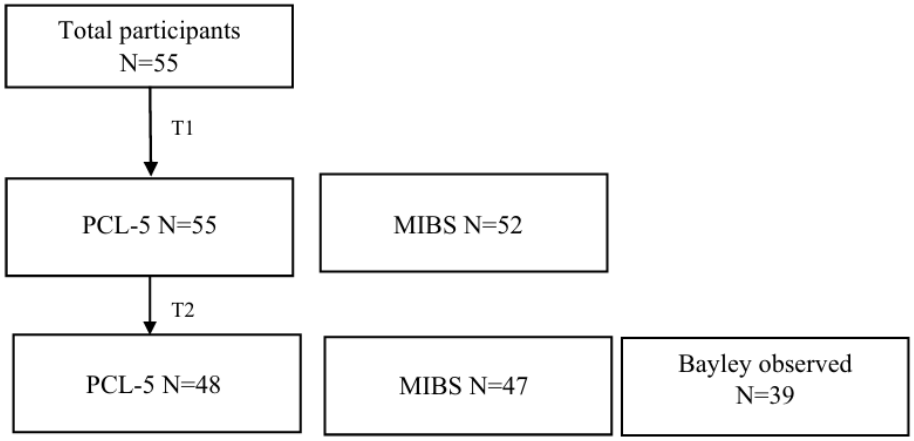

Figure 1. Flowchart of participants who completed the instruments of the main variables (PCL-5, MIBS, and Bayley). PCL-5 = PTSD Checklist for DSM-5. MIBS = Mother-Infant Bonding Scale.

0 (not at all) to 4 (extremely), with a higher score indicating more maternal PTSS (Weathers et al., 2013). PCL-5 BRS consists of items 1 to 8, and 10 to 11, e.g. repeated, disturbing, and unwanted memories of the stressful experience; avoiding memories, thoughts, or feelings related to recent childbirth (Weathers et al., 2013). PCL-5 GS consists of items 9, and 12 to 20, e.g. loss of interest in activities; feeling distant or cut off from other people (Weathers et al., 2013). The French version of the PCL-5 showed strong validity (Ashbaugh et al., 2016). In our study, Cronbach's alpha at six weeks was 0.89 and at six months was 0.90. For the subscale BRS, Cronbach's alpha was 0.90 at six weeks and 0.89 at six months. For the subscale GS, Cronbach's alpha at six weeks was 0.81 and at six months was 0.88; all of the above indicating good internal consistency.

Mother-infant bonding was measured with the Mother-Infant-Bonding Scale (MIBS), a self-report questionnaire consists of 8 items evaluating mothers' feelings towards their infants in the first few weeks after birth (Taylor et al., 2005). The MIBS has been used in infants aged six months in previous research (Takács et al., 2020). Items are rated on a 4-point Likert scale ranging from 0 (very much) to 3 (not at all) for items 1, 4, and 6, and on a reversed scale for the remaining items, with a higher value indicating poorer bonding. Moreover, the French version of the MIBS has been validated and showed an alpha score of 0.71 (Bienfait et al., 2017). In our study, the Cronbach alpha at six weeks was 0.55 and at six months was 0.52, indicating low internal consistency. After removing item 2, which had a low correlation, Cronbach alpha increased to 0.67 at six weeks and to 0.60 at six months. Low internal consistency of MIBS (0.68) was also observed in another study, even though this was a Swedish version of MIBS (Mörelius et al., 2021).

Infant development was assessed with the Bayley Scales of Infant Development, 3rd edition (Bayley III) (Bayley & Reuner, 2006), which encompasses a cognitive, a language, and a motor subscale. Raw scores from each scale were transformed into three standardised scores with a higher score indicating better development in three domains. The scales were administered in French by trained members of the research team based on a standardised protocol (Sandoz et al., 2019). Bayley Scales have been standardised and extensively reviewed for its psychometric quality and tested for reliability (r = 0.86–0.93) and validity using large samples of children with and without developmental delay (Bayley & Reuner, 2006).

Table 1. Descriptive characteristics of the participants (*n* = 55).

Variables	*M* (*SD*) or *n* (*%*)
Characteristics of mothers	
Maternal age	33.62 (4.6)
Nationality	
Swiss	26 (47.3)
European	19 (34.6)
Non-european	3 (5.4)
Missing values	7 (12.7)
Civil status	
Single	14 (25.5)
Married/cohabitating	33 (60)
Separated/divorced	1 (1.8)
Missing values	7 (12.7)
Education	
Primary education	1 (1.8)
Secondary education	1 (1.8)
Higher secondary education	2 (3.7)
Apprenticeship	16 (29.1)
University or university of applied sciences	27 (49.1)
Other	1 (1.8)
Missing values	7 (12.7)
Professional activity	
Working	32 (58.2)
Not working	15 (27.3)
Missing values	8 (14.5)
Parity	
Primipara	32 (58.2)
Multipara	23 (41.8)
History of traumatic birth	
Yes	19 (34.5)
No	17 (30.9)
Missing values	19 (34.5)
Characteristics of infants	
Sex of the infant	
Girls	27 (49.1)
Boys	28 (50.9)
Weeks of gestation	39.6 (1.3)
Birth weight (gram)	3273.2 (479.2)
Apgar at 5 minutes	9.33 (0.9)

Regarding maternal psychological vulnerabilities, maternal depression and anxiety symptoms were used as covariates for both outcomes. Maternal depression symptoms were measured with the Edinburgh Postnatal Depression Scale (EPDS), a self-report questionnaire evaluating the severity of postnatal depression symptoms over the past week (Cox et al., 1987). The 10 items are scored on a 4-point Likert scale from 0 to 3, with a higher total score indicating higher severity. The French version of the EPDS has been validated (Guedeney & Fermanian, 1998). The Cronbach alpha in our study when measuring at six weeks was 0.80 and at six months was 0.86, which demonstrated good internal consistency.

Anxiety symptoms were measured with the anxiety subscale of the Hospital Anxiety and Depression Scale (HADS-A). This self-report questionnaire consists of 7 items evaluating the severity of postnatal depression symptoms over the past week (Zigmond & Snaith, 1983). Items are scored on a 4-point Likert scale from 0 to 3, with a higher total score indicating higher severity. The French version of the HADS, including the HADS-A, has been previously validated (Bocéréan & Dupret, 2014). The Cronbach alpha in our study when measured at six weeks was 0.62 and at six months was 0.81, which is acceptable.
Infant temperament, as a covariate for the mother-infant bonding outcome, was measured with a maternal self-report instrument named the Infant Behavior Questionnaire – Revised Very Short Form (IBQ-R) consists of 37 items assessing the frequency of certain infant behaviours during the previous two weeks (Putnam et al., 2014). Good psychometric properties were reported for this questionnaire (Putnam et al., 2014). IBQ-R has three factors: Negative Emotionality (NEG), Positive Affectivity/Surgency (PAS), and Orienting/Regulatory Capacity (ORC). Based on previous studies, we only considered positive

temperament and negative temperament as potential covariates for bonding (Nolvi et al., 2016; Takács et al., 2020). Items are scored on a 7-point Likert scale from 1 (never) to 7 (always), with a higher score indicating higher negative behaviour (in NEG factor) or higher positive behaviour (in PAS factor). There was no validated French version of the IBQ-R available. The forward-backward method was applied for cultural adaptation and French translation as part of START study. The Cronbach alpha in our study for positive temperament was 0.75 and for negative temperament was 0.75.

Medical covariates, i.e., Apgar score (rapid standardised assessment of neonates after birth to determine the need for immediate resuscitation intervention (Apgar, 1953)) at 5 minutes, parity status, and sex of the infant were extracted from medical records. History of trauma (yes/no), civil status, (single, married/cohabiting, separated/divorced/widowed/ other), and education level (primary education, secondary education, upper secondary education, apprenticeship, university or school of applied sciences, other) were measured via a self-report sociodemographic questionnaire.

Statistical analyses

The statistical analyses were conducted with the software R, version 4.1.3 (R Core Team, 2021). Missing data for sociodemographic data is indicated in Table 1. Aside from those variables, for 55 participants, missing data included *n* = 3 MIBS at T1, *n* = 8 MIBS at T2, *n* = 15 Bayley, *n* = 3 HADS-A at T1, *n* = 8 HADS-A at T2, *n* = 3 EPDS at T1, and *n* = 8 EPDS at T2, *n* = 5 IBQ-R. For the purpose of analysis of the main outcomes, the missing data of main variables (the predictor and outcomes) was removed from the analysis since the missing values were not missing at random, preventing them from being imputed (Kang, 2013).

To test (cross-sectional and prospective) associations between maternal CB-PTSS and mother-infant bonding, we carried out statistical analyses without covariates (unadjusted model) and with covariates (adjusted model), as presented in Tables 2 and 3. For the adjusted model, potential covariates for mother-infant bonding were infant temperament (negative and positive emotionality), depression symptoms, anxiety symptoms, history of trauma, and parity. Only covariates significantly associated with the outcomes were introduced in the adjusted models (see Table 1 in supplementary material).

To test (cross-sectional and prospective) associations between maternal CB-PTSS and infant development outcomes (cognitive, motor, and language), we conducted bivariate linear regressions for the unadjusted models and adjusted models to test the significance of potential covariates (depression, anxiety, sex of the infants, and

Table 2. Linear regression PCL-5 and MIBS (unadjusted model).

Predictor	Dependent variable	N	B	95% CI	P
PCL-5 total at T1	MIBS at T1	50	0.152	[0.079, 0.224]	0.000***
PCL-5 GS at T1	MIBS at T1	50	0.268	[0.155, 0.381]	0.000***
PCL-5 BRS at T1	MIBS at T1	50	0.150	[0.009, 0.292]	0.037*
PCL-5 total at T1	MIBS at T2	45	0.064	[0.002, 0.127]	0.043*
PCL-5 GS at T1	MIBS at T2	45	0.101	[−0.004, 0.206]	0.059
PCL-5 BRS at T1	MIBS at T2	45	0.081	[−0.026, 0.188]	0.136
PCL-5 total at T2	MIBS at T2	46	0.033	[−0.014, 0.081]	0.166
PCL-5 GS at T2	MIBS at T2	46	0.021	[−0.054, 0.096]	0.574
PCL-5 BRS at T2	MIBS at T2	46	0.114	[0.014, 0.215]	0.025*

Note. BRS = birth-related symptoms. GS = general symptoms. MIBS = Mother-Infant Bonding Scale. PCL-5 = PTSD Checklist for DSM-5.
* $p < .05$.** $p < .01$.*** $p < .001$.

Table 3. Linear regression PCL-5 and MIBS (adjusting for EPDS and HADS-A).

Predictor	Dependent variable	N	B	95% CI	P
PCL-5 total at T1	MIBS at T1	50	0.134	[0.025, 0.243]	0.017*
PCL-5 GS at T1	MIBS at T1	50	0.306	[0.117, 0.496]	0.002**
PCL-5 BRS at T1	MIBS at T1	50	0.073	[−0.081, 0.228]	0.347

Note. BRS = birth-related symptoms. EPDS = Edinburgh Postnatal Depression Scale. GS = general symptoms. HADS-A = anxiety subscale of the Hospital Anxiety and Depression Scale. MIBS = Mother-Infant Bonding Scale. PCL-5 = PTSD Checklist for DSM-5.
* $p < .05$.** $p < .01$.*** $p < .001$.

Apgar score at 5 minutes) associated with cognitive, motor, and language development. Significant covariates were used in the adjusted model for multivariate regression analysis. In all analyses, p-values of < 0.05 were considered statistically significant. For mother-infant bonding outcomes, in the cross-sectional analysis at T1, from 52 participants, two outliers were identified through Mahalanobis distance ($p < .001$) and deleted (Tabachnick & Fidell, 2001). In the prospective analysis (PCL-5 at T1 and

MIBS at T2), for 47 participants, two outliers were identified and deleted. In the cross-sectional analysis at T2, for 47 participants, one outlier was identified and deleted. For infant development outcomes, no outliers were identified.

Results

Associations of maternal CB-PTSS and mother-infant bonding

The analysis of mother-infant bonding outcomes is described in Tables 2 and 3. In the unadjusted model at T1, significant cross-sectional positive associations were found: (1) between higher PCL-5 total score and higher MIBS total score (p = 0.000, B = 0.152, 95% CI 0.079–0.224, Cohen's f2 = 0.121); (2) between PCL-5 GS score and MIBS total score (p = 0.000 B = 0.268, 95% CI 0.155–0.381, Cohen's f2 = 0.475; and (3) between PCL-5 BRS score and MIBS total score (p = 0.037 B = 0.150, 95% CI 0.009–0.292, Cohen's f2 = 0.095). In the adjusted model (controlling for EPDS and HADS-A at T1), significant cross-sectional positive associations were found: (1) between PCL-5 total score and MIBS total score (p = 0.017, B = 0.134, 95% CI 0.025–0.243, Cohen's partial f2 = 0.133) and (2) between PCL- 5 GS score and MIBS total score (p = 0.002, B = 0.306, 95% CI 0.117–0.496, Cohen's partial f2 = 0.230).

In the cross-sectional analysis at T2, we found a significant positive association between PCL-5 BRS score and MIBS total score (p = 0.025, B = 0.114, 95% CI 0.014–0.215, Cohen's f2 = 0.121). No significant covariates were identified, thus we did not have an adjusted model for cross-sectional analysis between PCL-5 and MIBS at T2.

In the prospective analysis, in the unadjusted model, only a prospective significant positive association was found between PCL-5 total score and MIBS total score (p = 0.043, B = 0.064, 95% CI 0.002–0.127, Cohen's f2 = 0.371). No significant covariates were identified, thus we did not have an adjusted model for prospective analysis between PCL-5 and MIBS.

Associations of maternal CB-PTSS and infant development outcomes

In the prospective analysis shown in Table 4, for the unadjusted model, we found that higher BRS at T1 were associated with a higher infant cognitive subscale score of Bayley III at T2 (p = 0.026, B = 0.748, 95% CI 0.092–1.404). Cohen's f2 was 0.144, indicating a small-to -medium effect size (Cohen, 1988). For the adjusted model as shown in Table 5, we identified EPDS at T1 as a significant covariate for motor development but did not find any significant associations in this adjusted model.

For the cross-sectional associations between PCL-5 (total, GS, BRS scores) and infant development (cognitive, language, and motor) at T2, we did not find any significant associations. A significant covariate identified was EPDS at T2 but no significant results were found in this adjusted model.

Table 4. Linear regression PCL-5 and Bayley scale (cognitive, language, motor development) (unadjusted model).

Predictor	Dependent variable	n	B	95% CI	P
PCL-5 total at T1	Cognitive subscale of Bayley III	39	0.251	[−0.096, 0.599]	0.152
PCL-5 GS at T1	Cognitive subscale of Bayley III	39	0.163	[−0.440, 0.766]	0.587
PCL-5 BRS at T1	Cognitive subscale of Bayley III	39	0.748	[0.092, 1.404]	0.026*
PCL-5 total at T1	Motor subscale of Bayley III	39	0.166	[−0.214, 0.547]	0.381
PCL-5 GS at T1	Motor subscale of Bayley III	39	0.235	[−0.412, 0.882]	0.467
PCL-5 BRS at T1	Motor subscale of Bayley III	39	0.326	[−0.421, 1.074]	0.382
PCL-5 total at T1	Language subscale of Bayley III	39	−0.158	[−0.558, 0.240]	0.425
PCL-5 GS at T1	Language subscale of Bayley III	39	−0.137	[−0.817, 0.543]	0.686
PCL-5 BRS at T1	Language subscale of Bayley III	39	−0.427	[−1.204, 0.349]	0.272
PCL-5 total at T2	Cognitive subscale of Bayley III	39	0.147	[−0.178, 0.474]	0.365
PCL-5 GS at T2	Cognitive subscale of Bayley III	39	0.173	[−0.335, 0.683]	0.494
PCL-5 BRS at T2	Cognitive subscale of Bayley III	39	0.370	[−0.349, 1.089]	0.304
PCL-5 total at T2	Motor subscale of Bayley III	39	0.139	[−0.213, 0.491]	0.428
PCL-5 GS at T2	Motor subscale of Bayley III	39	0.141	[−0.408, 0.691]	0.604
PCL-5 BRS at T2	Motor subscale of Bayley III	39	0.393	[−0.381, 1.168]	0.310
PCL-5 total at T2	Language subscale of Bayley III	39	−0.166	[−0.534, 0.200]	0.364
PCL-5 GS at T2	Language subscale of Bayley III	39	−0.166	[−0.741, 0.407]	0.560
PCL-5 BRS at T2	Language subscale of Bayley III	39	−0.477	[−1.283, 0.328]	0.238

Note. BRS = birth-related symptoms. GS = general symptoms. PCL-5 = PTSD Checklist for DSM-5. * $p < .05$.** $p < .01$.*** $p < .001$.

Table 5. Linear regression PCL-5 and motor subscale of Bayley III (adjusted for EPDS).

Predictor	Dependent variable	n	B	95% CI	P
PCL-5 total at T1[a]	Motor subscale of Bayley III	39	−0.241	[−0.771, 0.288]	0.361
PCL-5 GS at T1[a]	Motor subscale of Bayley III	39	−0.587	[−0.524, 0.349]	0.211
PCL-5 BRS at T1[a]	Motor subscale of Bayley III	39	−0.150	[−1.017, 0.716]	0.726
PCL-5 total at T2[b]	Motor subscale of Bayley III	39	−0.279	[−0.781, 0.222]	0.266
PCL-5 GS at T2b	Motor subscale of Bayley III	39	−0.534	[−1.278, 0.209]	0.153
PCL-5 BRS at T2[b]	Motor subscale of Bayley III	39	−0.145	[−1.102, 0.811]	0.073

BRS = birth-related symptoms. EPDS = Edinburgh Postnatal Depression Scale. GS = general symptoms. PCL-5 = PTSD Checklist for DSM-5. [a]Adjusting for EPDS at T1. [b]Adjusting for EPDS at T2. * $p < .05$.** $p < .01$.*** $p < .001$.

Discussion

This longitudinal study specifically focused on a mode of birth associated with a higher risk of CB-PTSS: emergency C-sections (Yildiz et al., 2017). We found that higher maternal CB-PTSS (total score, BRS, GS) were cross-sectionally associated with lower mother-infant bonding at six weeks postpartum in the unadjusted model. After adjusting for depression and anxiety symptoms, cross-sectional associations between maternal CB-PTSS (GS and total score) and mother-infant bonding were still significant. At six months postpartum, significant associations emerged between BRS and mother-infant bonding in the unadjusted model. Prospectively, we found associations between a total score of CB-PTSS and mother-infant bonding in the unadjusted model. For infant development outcomes, we detected a prospective association between higher BRS and better cognitive infant development in the unadjusted model. However, the latter is likely due to a type-II error.

Our results showed mothers with more symptoms of maternal CB-PTSS had more difficulties in mother-infant bonding. Our cross-sectional results at six weeks postpartum aligned with several previous studies (Handelzalts et al., 2021, 2019; Nakić; Radoš et al., 2020; Stuijfzand et al., 2020). The prospective association found between maternal CB- PTSS and lower mother-infant bonding and the cross-sectional association between BRS and mother-infant bonding at six months postpartum are consistent with a previous study (Dekel et al., 2019).

Our unexpected finding showing infants of mothers with higher symptoms of BRS had better cognitive development is not consistent with previous studies that found either no association (Feeley et al., 2011) or a negative association (Garthus-Niegel et al., 2017; Parfitt et al., 2014). Noteworthy, these three studies did not test prospective associations between maternal CB-PTSS and infant development in infants younger than one-year-old and they did not differentiate between GS and BRS (Feeley et al., 2011; Garthus-Niegel et al., 2017; Parfitt et al., 2014). These methodological differences may partly explain the discrepancy of our findings with previous studies.

Alternatively, this unexpected result might reflect a type-II error. If this is the case, there may be no real significant relationship between these two variables, which is consistent with the study by Feeley, which also measured infant development at six months postpartum, although they tested the association cross- sectionally (Feeley et al., 2011). An alternative explanation may be that following traumatic childbirth, mothers have been reported to feel guilty (Ayers et al., 2019; Beck, 1996). They may feel also guilty towards their infants because they perceive themselves as not being good enough as mothers (Blegen et al., 2010; Venard et al., 2023) and may overcompensate and invest in their infants more, resulting in better infant cognitive development (Cook et al., 2018; Garthus-Niegel et al., 2020). However, this alternative explanation is contradicted by the fact that guilt is a negative emotion, which is included in GS and not BRS. In addition, we did not look into the role of fathers or other co-parents. This might cause bias, as father/co-parent – child interactions or any regular paternal involvement may affect the development of the children (Hall et al., 2014; Wang et al., 2005), especially the cognitive and psychological infant outcomes (Hall et al., 2014).

Our study is the first longitudinal study to identify the associations between CB- PTSS and infant development in infants under one-year-old whose mothers underwent emergency C-sections. We assessed infant development using validated and standardised clinical assessments. Moreover, we controlled for maternal and infant covariates in the analysis. However, some limitations must be pointed out. Our findings cannot be generalised to other modes of childbirth than emergency C-sections with term babies. Aside from that, the generalisability of our findings may be limited because a sizeable proportion of our participants were single mothers. According to one study, unmarried women had higher bonding with their infants compared to married women (Kinsey et al., 2014). The self-report questionnaire used to measure maternal CB-PTSS may not be as robust as an objective, clinical assessment to examine CB-PTSD. Nonetheless, PCL-5 is an appropriate instrument, as it is valid, reliable, and widely used in both research and clinical practice. In addition, the Cronbach alpha for MIBS in our participants was borderline and results should therefore be interpreted with caution. Replication of our results with a larger sample size, taking into consideration the involvement of the father or other co-parents is recommended. Furthermore, exploring mother-infant bonding and infant developmental trajectories over a longer period is a helpful recommendation for future studies. This extended investigation would provide a more comprehensive understanding of the dynamic processes involved. Moreover, objective measures of CB-PTSS and mother-infant interactions could be added in future studies.

Conclusion

Maternal CB-PTSS after emergency C-sections were associated with negative mother- infant bonding outcomes to some extent. Maternal CB-PTSS were not significantly associated with infant development. Further research is needed to replicate this study with a bigger sample size, controlling for father/co-parent involvement.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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9.4 Appendix D (study 2)

Journal of Affective Disorders

Early mother-infant interactions within the context of childbirth-related posttraumatic stress symptoms

--Manuscript Draft--

Manuscript Number:	
Article Type:	Research Paper
Keywords:	mother-infant interactions, coercions, reciprocity, traumatic childbirth, PTSS

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Abstract:	Background Childbirth can lead to perinatal mental health issues, such as childbirth-related posttraumatic stress symptoms (CB-PTSS), depression, and anxiety. Despite well explored mother-infant interactions in the context of maternal depression and anxiety, only limited studies investigated mother-infant interactions in the context of CB-PTSS, which is the aim of the present study. Methods A hundred mother-infant dyads in the French speaking part of Switzerland were classified into three groups: birth-related symptoms (BRS, i.e., symptoms of reexperiencing and avoidance) (n=20), general symptoms (GS, i.e., symptoms of negative cognition and mood and hyperarousal) (n=46), and non-symptomatic (NS) (n=34) based on maternal report on PTSD Checklist for DSM-5 (PCL-5). At six months postpartum, mother-infant interactions were video-recorded and their quality was assessed using the Global Rating Scale. Data was analyzed using ordinal logistic and negative binomial regressions. Results In the adjusted model, mothers in BRS group engaged in more frequent coercions compared to the NS group (B=-1.46, p=0.01, 95%CI=-2.63, -0.36) and showed lower reciprocity in their interactions with their infants compared to the GS group (B=1.21, p=0.03, 95%CI=0.05, 3.37). Limitations The use of a cross-sectional design limited the exploration of how consistent these findings are regarding mother-infant interactions between groups over time. Conclusions Mothers with higher BRS need support to improve interactions with their infants. Future studies should consider longitudinal design to observe mother-infant interaction changes between CB-PTSS groups over time.
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Cover Letter

March 13th 2024

Dear Prof. Brambilla and Prof. Soares,

Please consider the enclosed manuscript, entitled “Early mother-infant interactions within the context of childbirth-related posttraumatic stress symptoms”, for publication in the *Journal of Affective Disorders.*

Given the limited research on mother-infant interactions in the context of maternal childbirthrelated posttraumatic stress symptoms (CB-PTSS), we believe our study provides a novel perspective. To our knowledge, our study is the first to investigate mother-infant interactions in connection with symptom clusters (birth-related CB-PTSS, general CB-PTSS, and no CBPTSS) rather than the total score, providing a deeper understanding of the types of symptoms associated with quality of mother-infant interactions (e.g., maternal sensitivity, infant selfregulation, reciprocity).

This cross-sectional, observational study investigated differences in mother-infant interactions between CB-PTSS groups with infants aged six months. We used negative binomial and ordinal logistic regression to address our study aim. We observed that mothers in the birth-related CBPTSS group (more symptoms in re-experiencing and avoidance) were more intrusive in their interactions with their infants compared to the non-symptomatic group. Additionally, motherinfant dyads in this group displayed less reciprocity during their interactions compared to the general symptoms CB-PTSS group (more symptoms in negative cognition and mood, and hyperarousal). We reported our study in accordance with the STROBE guidelines.

Our results make an important contribution to the literature, deepening the understanding of mother-infant interactions within the context of maternal CB-PTSS. We believe that our study aligns with the scope of *Journal of Affective Disorders* and that our findings will be of interest to the multidisciplinary readership of your journal, including psychiatrists, psychologists, nurses, public health, and paediatricians.

The manuscript is original. There are no prior publications or submissions with any overlapping information. We declare no conflict of interest. All authors are responsible for the reported research. Antje Horsch will be serving as the corresponding author for this manuscript. She will assume responsibility for keeping the co-authors informed on the progress through the editorial process, including the content of the reviews and revisions made.

Yours sincerely,
Antje Horsch (on behalf of the co-authors)

Highlights

- Childbirth-related posttraumatic stress symptoms (CB-PTSS) consist of birth-related and general symptom clusters.
- This study compared mother-infant interactions between CB-PTSS groups.
- More maternal coercions/intrusions occurred in the birth-related CB-PTSS group.
- Higher mother-infant reciprocity was observed in the general symptom CB-PTSS group.
- Interventions aimed at tackling birth-related symptoms should be prioritized.

ABSTRACT

Background

Childbirth can lead to perinatal mental health issues, such as childbirth-related posttraumatic stress symptoms (CB-PTSS), depression, and anxiety. Despite well explored mother-infant interactions in the context of maternal depression and anxiety, only limited studies investigated mother-infant interactions in the context of CB-PTSS, which is the aim of the present study.

Methods

A hundred mother-infant dyads in the French speaking part of Switzerland were classified into three groups: birth-related symptoms (BRS, i.e., symptoms of re-experiencing and avoidance) (n=20), general symptoms (GS, i.e., symptoms of negative cognition and mood and hyperarousal) (n=46), and non-symptomatic (NS) (n=34) based on maternal report on PTSD Checklist for DSM-5 (PCL-5). At six months postpartum, mother-infant interactions were video-recorded and their quality was assessed using the Global Rating Scale. Data was analyzed using ordinal logistic and negative binomial regressions.

Results

In the adjusted model, mothers in BRS group engaged in more frequent coercions compared to the NS group (B=-1.46, p=0.01, 95%CI=-2.63, -0.36) and showed lower reciprocity in their interactions with their infants compared to the GS group (B=1.21, p=0.03, 95%CI=0.05, 3.37).

Limitations

The use of a cross-sectional design limited the exploration of how consistent these findings are regarding mother-infant interactions between groups over time.

Conclusions

Mothers with higher BRS need support to improve interactions with their infants. Future studies should consider longitudinal design to observe mother-infant interaction changes between CBPTSS groups over time.

Keywords: mother-infant interactions, coercions, reciprocity, traumatic childbirth, PTSS

Declaration of Interest Statement

Conflict of interest

The authors declared no potential conflicts of interest. Antje Horsch is on the management board of COST Action 22114.

Author Statement

CRediT authorship contribution statement

Devita Sella: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – Original draft, Project administration. **Bozicevic Laura:** Conceptualization, Investigation, Writing - Review & Editing. **Deforges Camille:** Investigation, Writing - Review & Editing. **Ciavarella Laura:** Investigation, Writing - Review & Editing. **Tolsa JeanFrançois:** Supervision, Writing - Review & Editing. **Sandoz Vania:** Conceptualization, Methodology, Investigation, Supervision, Writing - Review & Editing. **Horsch Antje:** Conceptualization, Methodology, Resources, Supervision, Writing - Review & Editing, Project administration.

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1. Introduction

Maternal mental health problems, including maternal childbirth-related posttraumatic stress symptoms (CB-PTSS), can affect the way mothers interact with their infants (Golds, Gillespie-Smith, Nimbley, & MacBeth, 2022; Ionio & Di Blasio, 2014). Maternal CB-PTSS refers to PTSS experienced by mothers following childbirth that disrupt daily acitvities but do not meet the diagnostic criteria for PTSD based on Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5) (American Psychiatric Association, 2022; Horsch et al., 2024). According to DSM-5, as in PTSD, CB-PTSS can be classified into four symptom clusters: reexperiencing (e.g., repeated, disturbing, and unwanted memories of traumatic childbirth), avoidance (e.g., avoiding memories, thoughts, or feelings related to the traumatic childbirth), negative cognition and mood (e.g., feeling distant from other people), and hyperarousal symptoms (e.g., feeling jumpy or easily startled) (American Psychiatric Association, 2022; Horesh, Garthus-Niegel, & Horsch, 2021). These four symptom clusters can be classified into two factors: birth-related symptoms (BRS, i.e., re-experiencing and avoidance symptoms) and general symptoms (GS, i.e., negative cognition and mood and hyperarousal symptoms) (Ayers, Wright, & Thornton, 2018; Sandoz et al., 2022). It is conceivable that various facets of PTSS may associate differently with various aspects of the experience of being a parent and relationship with own children. For instance, a study discovered that symptoms of reexperiencing and hyperarousal in male war veterans were not associated with parenting satisfaction, while avoidance symptoms were found being linked to parenting satisfaction (Samper, Taft, King, & King, 2004). Conversely, GS were associated with less bonding, whereas BRS was not (Nakić Radoš, Matijaš, Anđelinović, Čartolovni, & Ayers, 2020). Nevertheless, the two factors of CB-PTSS have not been explored in the context of motherinfant interactions – something our study will address.

Good-quality mother-infant interactions are characterized by positive affect as well as engaging dyadic exchanges that have been consistently associated with enhanced cognitive outcomes in infants (Poehlmann & Fiese, 2001). Moreover, maternal sensitivity also plays an important role in the interactions (Milgrom, Westley, & Gemmill, 2004). Maternal sensitivity denotes a mother's capacity to comprehend her infant's cues and to respond to them in a timely way, adjusting her actions accordingly, thus providing external support for the infant's emotional regulation and social exchanges (Ainsworth, Blehar, Waters, & Wall, 1979; Baker & McGrath, 2011; Feldman, 2012; Jaffe et al., 2001; Rattaz, Puglisi, Tissot, & Favez, 2022). When mothers lack sensitivity, interactions between mothers and their children are disruptive, leading to problems with child emotion regulation and lower

socioemotional development, such as behavior problems and poor social competences at 36 months of age (Leerkes, Blankson, &
O'Brien, 2009).

Despite the prevalence of maternal CB-PTSS of 12.3% reported by a recent meta-analysis which collected data from studies worldwide (Heyne et al., 2022), research on mother-infant interactions within the context of maternal CB-PTSS is still limited with mixed results. A recent meta-analysis focused on the associations between maternal CB-PTSS and mother-infant relationships found that more severe maternal CB-PTSS were associated with poorer quality of mother-infant relationships (Frankham, Thorsteinsson, & Bartik, 2023). However, this study mixed together data on quality of mother-infant bonding and mother-infant interactions (Frankham et al., 2023). Frankham et al. (2023) only included one study that specifically investigated mother-infant interactions, which found that higher maternal CB-PTSS was associated with lower sensitivity during interactions with their children and mothers being less effective at structuring social interaction at six months postpartum (Feeley et al., 2011).

Aside from sensitivity, during the still-face stress paradigm (Tronick, Als, Adamson, Wise, & Brazelton, 1978) mothers with higher CB-PTSS displayed more avoidance (e.g., did not look directly at their infants during play and reunion in still-face paradigm) and more intrusive behavior (e.g., touching or making noise to catch the infant's attention) to their three months old infants (Ionio & Di Blasio, 2014). Their infants showed more crying and disorganized behaviors during the free-play and avoidance or looking away in the still-phase compared to dyads with less CB-PTSS (Ionio & Di Blasio, 2014). The still-face stress paradigm is an experimental approach to assess infant's reactions to socio-emotional stress that consists of three phases: (1) an initial episode of normal interaction serving as a baseline, (2) the 'still-face' episode where the mother becomes unresponsive and maintains a neutral facial expression, and (3) a reunion phase where normal interaction is resumed (Tronick et al., 1978). However, another study found no correlations between maternal CB-PTSS and quality of mother-infant interactions at three months postpartum (Parfitt, Pike, & Ayers, 2013). Differences in populations, sample sizes, and measurement instruments among these three studies could contribute to different findings (Feeley et al., 2011; Ionio & Di Blasio, 2014; Parfitt et al., 2013). Therefore, associations between maternal CB-PTSS and quality of mother-infant relationships need further exploration.

The purpose of this study was to investigate differences in the quality of mother-infant interactions in the context of different symptom clusters of maternal CB-PTSS. We hypothesized that mother-infant interactions would be different between groups.

2. Methods

2.1 Participants

To determine the differences in mother-infant interactions between groups in the context of CBPTSS, we classified participants into three groups: BRS, GS, and NS based on maternal report on PTSD Checklist for DSM-5 (PCL-5) (see below on instruments section for more detail). Medium-to-large effects were expected based on previous study (Feeley et al., 2011). A total sample 75 dyads would be sufficient to detect a significant effect of $\eta 2$ = 11.8% with a power of 80%, while a total sample of 90 dyads would permit to detect effects larger than 10%. The present study consisted of two phases. In phase 1 (retrospective), we utilized data from the control group (n=38) of a randomized controlled trial on the prevention of CB-PTSD following unplanned cesarean section (NCT 03576586) (Deforges et al., 2023; Sandoz et al., 2019). Phase 2 was conducted to achieve the required total sample size. In the end, we collected n=62 in phase 2, which altogether makes a total sample size of n=100 mother-infant dyads.

Inclusion criteria were mothers speaking French or English with term (gestational weeks ≥37) healthy infants, who gave written consent. Exclusion criteria were insufficient French or English language skills to participate, current psychotic illness, intellectual disability, severe illness of mothers or infants, alcohol abuse or illegal drug use during pregnancy.

2.2 Procedure

In phase 1, women were recruited when they underwent unplanned cesarean sections at Swiss University Hospital. The procedure detailed below only concerned phase 2, for a detailed explanation of the procedure in phase 1, please refer to the study protocol (Sandoz et al., 2019). Nevertheless, both phases followed the similar procedure for data collection. The local ethics committee approved the studies for phases 1 (2017-02142) and 2 (2022-00716).

Recruitment and data collection took place between August 2022 to September 2023. We distributed advertisements seeking participants in the development unit at a French-speaking Swiss University Hospital, day cares, clinics of gynecologists and pediatricians. Additionally, we posted advertisement online on the French-speaking Swiss University Hospital website and on social media platforms (Instagram, Facebook, LinkedIn) allowing us to reach more people.

Eligible participants received further explanations about the research, including the purpose of the study, procedures, risks and benefits, and approximate duration of the study. They were informed that the participation in the study was entirely voluntary. Further, once they agreed to participate, they were required to sign a written informed consent. All mother-infant dyads would be eligible up to six months postpartum. Therefore, data collection was scheduled for approximately six months postpartum for those infants who had not yet reached this age at the time of recruitment.

We asked participants to complete maternal self-report questionnaires online using the Research Electronic Data Capture (REDCap) (Harris et al., 2009). About one week later, mothers and infants were invited to the University Hospital to film the interactions. The session took place in a single room equipped with two moveable cameras mounted on opposite walls. Mothers were instructed to play with their infants as they would at home using a standardized set of toys provided by the researchers. All mother-infant dyads used the same set of toys. Freeplay sessions were recorded for 15 minutes. In cases where participants (n=47) could not come to the hospital due to scheduling conflicts or transportation difficulties, appointments were scheduled at their homes. The same procedure was followed during these home visits, with only one camera being used.

2.3 Instruments

Sociodemographic and obstetrical data were collected through maternal self-report questionnaire, as reported in Table 1.

Maternal CB-PTSS

PTSD Checklist for DSM-5 (PCL-5) is a 20-item self-report questionnaire assessing PTSD over the past month (Weathers et al., 2013). The traumatic event in the questionnaire was named as "traumatic childbirth". Participants responded using a Likert scale from 0 (not at all) to 4 (extremely), with a higher score indicating symptoms (Weathers et al., 2013). The French version of the PCL-5 showed strong validity (Ashbaugh, Houle-Johnson, Herbert, El-Hage, &
Brunet, 2016). In our study, Cronbach's alpha for PCL-5 was 0.89, indicating a strong internal consistency.

Symptoms are counted when they are present as a score of two or higher (American Psychiatric Association, 2022). Based on participants' responses to the PCL-5, they were divided into three groups (NS, BRS, GS). Dyads were assigned to the BRS group if the mother scored two or higher on BRS-related items (items 1 through 8 and 10 to 11). Conversely, if her score was two or higher on GS-related items (items 9 and 12 through 20), the dyad was placed in the GS group. If none of the items scored two or higher, the dyad was classified into the NS group. In cases where mothers' total scores for both BRS and GS were equal, we prioritized assigning her and her infant to the BRS group. This was based on studies demonstrating that re-experiencing symptoms (BRS) were linked to less positive infant outcomes, specifically in motor development (Garthus-Niegel, Ayers, Martini, von Soest, & Eberhard-Gran, 2017), and that avoidance symptoms (BRS) were associated with lower parenting satisfaction (Samper et al., 2004).

Mother-infant interactions

The Global Rating Scale (GRS), a parent-child interaction coding scheme (Murray & Karpf, 2000), was used to code three minutes (from minute three to six) out of 15 minutes video-taped mother-infant interactions and assess its quality. We utilized a three-minute duration for coding the interactions, consistent with the methodology of previous studies (Parfitt et al., 2013; Salih et al., 2023). Interactions were coded by three reliable coders who previously got trained and completed the reliability test, with interrater reliabilities ≥ 0.79 for all the subscales of GRS. This coding scheme had been used by several studies looking into mother-infant interactions in various clinical conditions (Cooper et al., 2009; Ionio et al., 2022; Seager et al., 2018).

The standardized and validated coding scheme includes nine subscales which assess infant behaviors (two scales), maternal behaviors (five scales), and joint behaviors (two scales). Infant subscales include emotional tone and self-regulation. Emotional tone of infants refers to how content the infant is during interactions, while self-regulation measures how well infants regulate their emotional and physical responses to certain events during the interactions (Murray & Karpf, 2000).

Maternal subscales include positive and negative expressed emotions, maternal coercions or intrusions, maternal emotional tone, and sensitivity (Murray & Karpf, 2000). Maternal expressed emotions are comments from the mothers that could be positive, affectionate, complimentary, or negative and critical, directed at the infant. To score these maternal expressed emotions, we needed to transcribe and translate the interactions into French or English. Maternal coercions or intrusions refers to forceful positioning or guidance that cut across or disrupt the infant's activity. Maternal emotional tone pertains to the level of contentment displayed during interaction. Maternal sensitivity refers to how attuned the mother is to the infant's signals.

Joint subscales include general atmosphere and reciprocity during play. Reciprocity assesses whether there is turn-taking and sharing attention during interactions. General atmosphere refers to whether the mother and infant's overall contact is pleasant or disharmonious (discordant and conflictual). In total, we had nine subscales to assess mother-infant interactions. All subscales were coded on a 5-point rating scale, with higher scores indicating better outcomes (e.g., more sensitive, more self-regulated), except for positive and negative expressed emotions, and maternal coercions, which were measured as event counts. In the analysis, each subscale was analyzed separately.

Maternal mental health

Maternal depression and anxiety symptoms were measured as potential covariates as studies shown these often comorbid with CB-PTSS (Milgrom et al., 2004; Parfitt et al., 2013; Rousseau, Feldman, Shlomi Polachek, & Frenkel, 2023). Maternal depression symptoms were measured with the Edinburgh Postnatal Depression Scale (EPDS), a self-report questionnaire evaluating the severity of postnatal

depression symptoms over the past week (Cox, Holden, & Sagovsky, 1987). The 10 items are scored on a 4-point Likert scale from 0 to 3, with a higher total score indicating higher severity. The French version of the EPDS has been validated
(Guedeney & Fermanian, 1998). In our study, Cronbach's alpha for EDPS was 0.85, indicating a strong internal consistency.

Anxiety symptoms were measured with the anxiety subscale of the Hospital Anxiety and Depression Scale (HADS-A). This self-report questionnaire consists of 7 items evaluating the severity of postnatal anxiety symptoms over the past week (Zigmond & Snaith, 1983). Items are scored on a 4-point Likert scale from 0 to 3, with a higher total score indicating higher severity. The French version of the HADS, has been previously validated (Bocéréan & Dupret,
2014). In our study, Cronbach's alpha for HADS-A was 0.77, indicating a moderate level of internal consistency.

Statistical analyses

The statistical analyses were conducted with the software R, version 4.1.3 (R Core Team, 2021). A normality check was done for each variable with Shapiro-Wilk test. Normal distributed data (maternal age, infants' birthweight) is presented in mean and standard deviation (SD), while data with non-normal distribution (PCL-5, HADS-A, EPDS, APGAR, gestational week) is presented in median and interquartile (IQR) in Table 1. CB-PTSS group differences in sociodemographic and obstetrical data were examined with Kruskal Wallis (for continuous variables) or Chi-Square (for categorical variables) tests, as indicated in Table 1.

Table 2 shows the descriptive data of mother-infant interactions at six months postpartum. Results from the main analysis are presented in Table 3 and Table 4. For the main analysis, since the data on GRS subscales were not normally distributed, ordinal logistic regression was applied to investigate group differences of six subscales of the GRS with Likert scales (i.e., infant emotional tone, infant self-regulation, mother emotional tone, maternal sensitivity, atmosphere of the interactions, and reciprocity). Group differences for maternal positive/negative expressed emotion and maternal coercions were analyzed using negative binomial regression because they were calculated as event counts, unlike other GRS subscales, which were rated on a Likert scale. None of the mothers expressed negative emotion, thus, this maternal subscale of the GRS was excluded from the analysis.

There were no missing values in the main variables, except for maternal positive expressed emotion, where data from two participants were missing because researchers were unable to recognize the language used. This occurred because mothers were instructed to interact naturally as they would at home with their infants, sometimes resulting in the use of their native languages. Missing

sociodemographic and obstetrical data is shown in Table 1. Since the percentage of the missing data was small (less than 3%), a listwise or case deletion approach was applied, where we did not include the missing values in the analysis (Kang, 2013). Moreover, for maternal negative expressed emotion, the score was zero for all mothers; thus, we did not present it in Table 2 and did not include it in further analysis. Finally, we conducted a sensitivity analysis to test whether the phase of the recruitment influenced the results.

3. Results

3.1 Descriptive statistics

A total of 100 mother-infant dyads participated. Among these, 34 dyads were in NS group, 20 in BRS group, and 46 in GS group. In total, the mean age of participants was 33.58 years (SD=4.19). Overall, 63% (n=63) of mothers were Swiss and 80% (n=80) were married, cohabitated, or were in a relationship. The majority of mothers (73%, n=73) had received a university education, and were multipara (61%, n=61). The number of mothers who had a vaginal birth or underwent unplanned cesarean sections were the same (46%, n=46). There were 51 female (51%) and 49 male (49%) infants. Further details on participant demographic information for each group is presented in Table 1.

We also examined the differences between groups in terms of sociodemographic, obstetrical, and maternal mental health data using Kruskal Wallis (for continuous variables) or Chi-Square (for categorical variables) tests. We found six variables (history of past trauma, EPDS, HADSA, PCL-5, gestational weeks, APGAR score) were significantly different (p<0.05), as shown in Table 1. Moreover, a higher proportion of mothers in BRS group had a history of past trauma compared to the GS and NS groups. Mothers in the GS group had higher EPDS, HADS-A, and PCL-5 compared to those in the BRS and NS groups. Table 2 provides a comprehensive overview of scores across various subscales of the GRS, including median values and interquartile ranges (IQR) in general and for each group (NS, BRS, GS).

3.2 Differences of mother-infant interactions between groups

We employed negative binomial regressions to analyze maternal positive expressed emotion and maternal coercions, as they were measured as event counts. Additionally, ordinal logistic regression analysis was conducted for assessing variables measured on a Likert scale, including maternal emotional tone, maternal sensitivity, infant emotional tone, infant self-regulation, general atmosphere, and reciprocity. The unadjusted model of negative binomial and ordinal logistic regression analysis indicated no significant group differences in any of the GRS subscales (p>0.05) during free-play mother-infant interactions, as presented in Table 3.

As some of the sociodemographic, obstetrical, and maternal health data (see Table 1) showed significant differences between groups, we added these six variables in the adjusted model. In Table 4, the adjusted model showed that the BRS group had significantly more frequent coercions compared to the NS group (B=-1.46, p=0.01, 95%CI=-2.63, -0.36) and showed lower reciprocity in their interactions

with their infants compared to the GS group (B=1.21, p=0.03, 95%CI=0.05, 3.37). Finally, the sensitivity analysis showed the results of the adjusted analysis did not change depending on the phase of recruitment (data not shown).

4. Discussion

The objective of this study was to explore the differences of mother-infant interactions between groups based on different maternal CB-PTSS clusters (BRS, GS, and NS) at six months postpartum. Our study demonstrates that mother-infant interactions (infant emotional tone, infant self-regulation, maternal emotional tone, maternal expressed emotion, maternal coercions, maternal sensitivity, general atmosphere, and reciprocity) at six months postpartum did not differ significantly between groups of maternal CB-PTSS. However, after adjusting for covariates, we found that mothers of the BRS group engaged in more frequent coercions compared to the NS group and showed lower reciprocity in their interactions with their infants compared to the GS group.

Our finding regarding the maternal coercions / intrusions is in line with a study by Ionio and Di Blasio (2014) who also found that mothers with more CB-PTSS were more intrusive during their interactions with their infants. They suggested that mothers with more symptoms were feeling more anxious and insecure when the attentions of the infants were not on them, thus mothers touched their infants more and made more noise to re-focus their infant's attentions onto them (Ionio & Di Blasio, 2014). Despite similar findings, there were differences in our study and the study by Ionio and Di Blasio (2014). They used a still-face stress paradigm at three months, while our study used a free-play (normal social interaction) paradigm at six months. Moreover, we used a different instrument to code the interactions. In our coding, not all maternal touch was counted as coercions. Maternal behaviors were only rated as coercive when they interrupted infant activities. Finally, Ionio and Di Blasio (2014) did not distinguish between BRS and GS. Our study clearly indicates that the BRS are particularly related to maternal coercive behaviors.

In addition, our findings suggest higher levels of reciprocity during mother-infant interactions in the GS group compared to the BRS group. This indicates that increased symptoms related to re-experiencing and avoidance in mothers are associated with less reciprocity during interactions, in contrast to those experiencing more symptoms related to negative cognition and hyperarousal. This could imply that mothers affected by re-experiencing symptoms might be distracted, potentially resulting in reduced attentiveness to their child's signals. Similarly it could be suggested that mothers with more avoidance symptoms may not be able to pay full attention to their infant during the interaction and thus miss some important cues their infant sends. Indeed, Ionio and Di Blasio (2014) reported that mothers with high CB-PTSS scores did not directly look at their infants' faces during play and reunion sessions during a still-face paradigm and that their infants tended to look away during still-episode that might contribute to less reciprocity during interactions. Nevertheless, these were two different paradigms (freeplay and still-face), and future research is thus needed to confirm our findings.

In contrast to a study by Feeley et al. (2011), we did not find differences in maternal sensitivity between groups. Different study samples might contribute to this different finding, as in Feeley et al. (2011) the participants were mother-infant dyads whose infants had been hospitalized in the NICU. Moreover, Feeley et al. (2011) did not control for maternal depression and anxiety that were comorbid with maternal CB-PTSS (Horsch et al., 2024). Nevertheless, Rousseau et al. (2023) also found that more severe and persistent CB-PTSS were related to lower maternal sensitivity. Although Rousseau et al. (2023) controlled for maternal depression and anxiety, their infants were younger (four months old) than ours which might explain our different results. It is reasonable to assume that interactions occurred closer to the event of birth, when traumatic, may result in maternal CB-PTSS more strongly associated with less sensitivity during interactions.

One of the innovative aspect of this study is that we grouped dyads based on their symptom classifications (i.e., NS, BRS, and GS) instead of using the total score calculation or classification based on certain cut-off points as in previous studies (Feeley et al., 2011; Ionio & Di Blasio, 2014; Muller-Nix et al., 2004; Parfitt et al., 2013). This provides a new insight on the quality of mother-infant interactions in terms of symptom clusters. However, potential bias may arise in dyads classification for mothers with equal BRS and GS total scores when assigning them to the BRS group, as this has not been thoroughly investigated in previous research. Our decision was influenced by studies suggesting that BRS symptoms often have more pronounced effects, such as being associated with lower parenting satisfaction (although this study focused on war-related PTSD in fathers) and less positive infant outcomes (GarthusNiegel et al., 2017; Samper et al., 2004). However, another study found that BRS was not associated with bonding but rather associated with GS (Nakić Radoš et al., 2020).

Moreover, our study included a larger sample size compared to previous studies on motherinfant interactions in the context of CB-PTSS (Feeley et al., 2011; Ionio & Di Blasio, 2014). Nonetheless, this study has some limitations. We did not extensively measure maternal prenatal mental health, which might influence the results, as prenatal anxiety symptoms might be associated with quality of mother-infant interactions (Parfitt et al., 2013). Moreover, we did not take into account any measure of the co-parents. The use of a cross-sectional design limited the exploration of how consistent these findings are regarding mother-infant interactions between groups over time. Even though this design was sufficient for our study aim, it would be helpful if future studies could include longitudinal studies to provide additional insights into the longterm implications of maternal CB-PTSS on mother-infant interactions, as one study suggested that the persistence of CB-PTSS across different timepoints is associated with mother-infant interactions (Rousseau et al., 2023). Furthermore, further studies should examine whether our findings can be replicated when the mother-infant interactions take place in a still-face stress paradigm.

In conclusion, our results indicate that PTSS specifically related to childbirth are associated with a higher frequency of maternal coercions and lower reciprocity during interactions with their infants at six months postpartum compared to mothers exhibiting no symptoms or experiencing general PTSS. Interventions aimed at tackling birth-related symptoms should be prioritized (compared to general symptoms when the resources are limited) to improve their interactions with their infants, making them less coercive and fostering improved reciprocity. However, our results also suggest that mothers experiencing these symptoms might feel reassured, as other aspects of interactions (i.e., maternal sensitivity, emotional tone, infant selfregulation) did not differ significantly between mothers with and without symptoms. Therefore, mothers could improve their interactions with their infants without excessive concern about potentially putting their infants at risk due to the consequences of the CB-PTSS they experience.

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Table 1. Participant characteristics and significance tests for comparison between CB-PTSS groups (n=100)

Variables	NS (n=34)	BRS (n=20)	GS (n=46)	P value
Mothers (n=100)				
Maternal age (years) – mean (S.D)	34.41 (4.42)	32.30 (4.54)	33.52 (3.79)	0.34[a]
Nationality N (%) Swiss				
European	24 (70.59)	11 (55)	28 (60.87)	0.635[b]
Non-european	8 (23.53)	7 (35)	13 (28.26)	
Missing values	2 (5.88)	1 (5)	4 (8.70)	
			1 (2.7)	
Relationship status N (%) Single				
Married / cohabitating	4 (11.76)	2 (10)	9 (19.57)	0.45[b]
Separated / divorced	29 (85.29)	16 (80) 1	35 (76.09)	
Other		(5)		
Missing values	1 (2.94)		1 (2.17)	
		1 (5)	1 (2.17)	
Education N (%)				
Secondary education	1 (2.94)			0.68[b]
Higher secondary education	2 (5.88)			
Apprenticeship	5 (14.71)	5 (25)	9 (19.57)	
University or university of applied	25 (73.53)	14 (70)	34 (73.91)	
sciences			2 (4.35)	
Other	1 (2.94)	1 (5)	1 (2.17)	
Parity N (%)				0.92[b]
Primipara	7 (20.59)	5 (25)	8 (17.39)	
Multipara	27 (79.41)	15 (75)	38 (82.61)	
Mode of childbirth N (%)				0.87[b]
Vaginal birth	15 (44.12)	10 (50)	21 (45.65)	
Planned cesarean section	1 (2.94)		1 (2.17)	
Vacuum-assisted vaginal	1 (2.94)	2 (10)	2 (4.35)	
Forceps delivery	1 (2.94)			
Unplanned cesarean section	16 (47.06)	8 (40)	22 (47.83)	
History of past trauma N (%)				0.01*[b]
Yes	4 (11.76)	9 (45)	16 (34.78)	
No	30 (88.24)	10 (50)	29 (63.04)	
Missing values		1 (5)	1 (2.17)	

Maternal depression symptoms (EPDS) - median (IQR)	3.50 (3.75)	7 (3.75)	7.50 (8.50)	0.01*[a]
Maternal anxiety symptoms (HADS-A) - median (IQR)	3 (3)	5 (2.50)	7 (3.75)	0.01*[a]
Maternal CB-PTSS (PCL-5) - median (IQR)	2 (2.75)	10.50 (5)	11 (11)	0.01*[a]
Infants (n=100)				
Sex of the infant N (%)				
Girls	18 (52.94)	12 (60)	21 (45.65)	0.54[b]
Boys	16 (47.06)	8 (40)	25 (54.35)	
Gestational weeks - median (IQR)	40 (2)	40.35 (1.10)	40 (1.5)	0.01*[a]
Birthweight (gram) - mean (S.D)	3316 (433)	3358 (592)	3369 (485)	0.86[a]
APGAR at 5 minutes - median (IQR)	10 (1)	9 (1)	9 (1)	0.01*[a]

Note: Non-symptomatic (NS), Birth-Related Symptoms (BRS), General Symptoms (GS). [a]Kruskal-wallis test. [b]Chi-square test. Please note some variables are presented as median and IQR because the data were not normally distributed.

Table 2. Descriptive data of Global Rating Scale

	Total (n=100) Median (IQR)	NS (n=34) – Median (IQR)	BRS (n=20) – Median (IQR)	GS (n=46) - Median (IQR)
Infant emotional tone[1]	4 (1)	3.5 (1)	3 (1)	4 (1)
Infant self-regulation[1]	5 (1)	4.5 (1)	5 (1)	5 (1)
Maternal emotional tone[1]	4 (1)	4 (1)	4 (0.25)	4 (1)
Maternal positive expressed emotion[2]	0 (1)	0 (1)	0 (1)	0 (2)
Maternal coercions[2]	0 (1)	0 (1)	0 (1)	0 (1)
Maternal sensitivity[1]	4 (2)	3.5 (2)	3.5 (2.25)	4 (2)
General atmosphere[1]	4 (1)	4 (2)	4 (2)	4 (1)
Reciprocity[1]	4 (1)	4 (0.75)	4 (1)	5 (1)

Note: Non-symptomatic (NS), Birth-Related Symptoms (BRS), General Symptoms (GS). [1]range from 1-5; [2]event count. Please note results are presented as median and IQR because the data were not normally distributed.

Table 3. Comparison of GRS between groups – unadjusted model (ordinal logistic regression and negative binomial regression)

	NS (n=34)		BRS (n=20)	GS (n=46)	
	Coefficient	P value (95%CI)	Reference group	Coefficient	P value (95%CI)
Infant emotional tone[1]	0.01	0.97 (-1.02, 1.04)	Ref	0.72	0.15 (-0.26, 1.70)
Infant self-regulation[1]	-0.45	0.41 (-1.54, 0.63)	Ref	-0.17	0.73 (-1.21, 0.85)
Maternal emotional tone[1]	0.11	0.83 (-0.93, 1.15)	Ref	0.51	0.31 (-0.47, 1.50)
Maternal positive expressed emotion[2]	0.45	0.37 (-0,55, 1.46)	Ref	0.52	0.27 (-0.43, 1.48)
Maternal coercions[2]	-0.33	0.50 (-1.33, 0. 64)	Ref	-0.25	0.59 (-1.18, 0.67)
Maternal sensitivity[1]	0.25	0.62 (-0.77, 1.28)	Ref	0.65	0.18 (-0.31, 1.61)
General atmosphere[1]	-0.02	0.96 (-1.06, 1.02)	Ref	0.29	0.55 (-0.68, 1.28)
Reciprocity[1]	0.01	0.97 (-1.00, 1.03)	Ref	0.79	0.12 (-0.20, 1.80)

Note: Non-symptomatic (NS), Birth-Related Symptoms (BRS), General Symptoms (GS). [1]ordinal logistic regression; [2] negative binomial regression

Table 4. Comparison of GRS between groups – adjusted model (ordinal logistic regression and negative binomial regression)

	NS (n=34)		BRS (n=20)	GS (n=46)	
	Coefficient	P-value (CI)	Reference group	Coefficient	P-value (CI)
Infant emotional tone[1]	0.70	0.27 (-1.26, 0.97)	Ref	0.84	0.12 (-1.92, 0.22)
Infant self-regulation[1]	-0.31	0.65 (-1.67, 1.05)	Ref	-0.12	0.84 (-1.29, 1.05)
Maternal emotional tone[1]	0.44	0.51 (-0.86, 1.74)	Ref	0.47	0.41 (-0.64, 1.59)
Maternal positive expressed emotion[2]	0.35	0.52 (-0.75, 1.48)	Ref	0.08	0.86 (-0.93, 1.12)
Maternal coercions[2]	-1.46	0.01 (-2.63, -0.36)*	Ref	-0.30	0.48 (-1.14, 0.55)
Maternal sensitivity[1]	0.49	0.44 (-0.77, 1.76)	Ref	0.48	0.38 (-0.60, 1.56)
General atmosphere[1]	0.50	0.45 (-0.80, 1.80)	Ref	0.46	0.41 (-0.64, 1.57)
Reciprocity[1]	0.63	0.33 (-0.65, 1.92)	Ref	1.21	0.03 (0.05, 2.37)*

Note: Non-symptomatic (NS), Birth-Related Symptoms (BRS), General Symptoms (GS). [1]ordinal logistic regression; [2]negative binomial regression. Adjusted for PCL-5, HADS-A, EPDS, past trauma, APGAR, gestational weeks.

9.5 Appendix E (study 3)

Journal of Affective Disorders

Mother-infant physiological and behavioral synchrony in the context of childbirth-related posttraumatic stress symptoms

--Manuscript Draft--

Manuscript Number:	
Article Type:	Research Paper
Keywords:	Physiological synchrony, behavioral synchrony, heart rate variability, traumatic childbirth, reciprocity, interactions.
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Abstract:	Synchrony of mother-infant interactions is crucial for infant development. However, the extent of mother-infant physiological synchrony in the context of maternal childbirthrelated posttraumatic stress symptoms (CB-PTSS) remains unknown. This study aimed to investigate physiological synchrony within the context of CB-PTSS. Additionally, it investigated the association between mother-infant physiological and behavioral synchrony. A total of 86 French or English-speaking mothers and their term infants participated. Maternal CB-PTSS was assessed using the PTSD Checklist for DSM-5 (PCL-5) modified for childbirth. Mother-infant dyads were classified into groups based on their responses to the PCL-5. During interactions, physiological synchrony was measured using heart rate variability (HRV), while behavioral synchrony (reciprocity) was observed in video recordings. Dyads' physiological synchrony were classified into negative (opposite HRV fluctuations) and positive (same HRV fluctuations). Physiological synchrony was observed between mothers and their infants for negative dyads (β=-0.029, p=.033). Coefficient distributions were not significantly different between CB-PTSS groups in positive (F(2, 37)=2.08, p=.14) and negative dyads (F(2, 37)=0.89, p=.42). No significant associations between physiological and behavioral synchrony in the positive dyads (F(1, 33)=1.76, p=.19), or in the negative ones (F(1, 34)=0.06, p=.80) were found. Cross-sectional design limits exploring the association between physiological and behavioral synchrony over time within the context of maternal CB-PTSS. Although we did not find differences in physiological synchrony between groups and observed no association between behavioral and physiological synchrony, our findings suggest there was mother-infant physiological synchrony. Further similar studies controlling for individual physiological regulation, maternal anxiety, and maternal depression are recommended.
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Cover Letter

January 25th 2024

Dear Prof. Brambilla and Prof. Soares,

Please consider the enclosed manuscript, entitled “Mother-infant physiological and behavioral synchrony in the context of childbirth-related posttraumatic stress symptoms”, for publication in the *Journal of Affective Disorders.*

Given the lack of studies on maternal childbirth-related posttraumatic stress symptoms (CBPTSS) and mother-infant synchrony, especially regarding physiological synchrony, we believe our study addresses an important gap.

This cross-sectional study investigated mother-infant physiological synchrony within the context of maternal CB-PTSS at six months postpartum. Further, we also explored the association between mother-infant physiological and behavioral synchrony. We used several different statistical approaches to confirm our findings. We observed mother-infant physiological synchrony within the context of maternal CB-PTSS. However, we did not find physiological synchrony different between groups. Moreover, no association observed between physiological and behavioral synchrony. Our study was reported in accordance with the STROBE guidelines.

Our results make an important contribution to the literature on the exploration of physiological synchrony within the context of maternal CB-PTSS. Our study is the first to investigate the associations between physiological and behavioral synchrony within the context of CB-PTSS. We believe that our results will be of interest to the multidisciplinary readership of your journal, including psychiatrists, psychologists, nurses, and paediatricians. We therefore believe that this manuscript falls in the scope of *Journal of Affective Disorders.*

The manuscript is original. There are no prior publications or submissions with any overlapping information, including studies and patients. We declare no conflict of interest. All authors are responsible for the reported research. Antje Horsch will be serving as the corresponding author for this manuscript. She will assume responsibility for keeping the co-authors informed on the progress through the editorial process, including the content of the reviews and revisions made.

Yours sincerely,
Antje Horsch (on behalf of the co-authors)

Highlights

- First study examining mother-infant physiological and behavioral synchrony in the context of maternal CB-PTSS.
- Physiological synchrony was observed between mothers and infants during social interactions.
- Physiological synchrony was not significantly different between CB-PTSS groups (birth-related symptoms, general symptoms, and non-symptomatic).
- No significant association between physiological and behavioral synchrony in the dyads.

Abstract

Mother-infant physiological and behavioral synchrony in the context of childbirthrelated posttraumatic stress symptoms

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Introduction

Synchrony of mother-infant interactions is crucial for infant development. However, the extent of mother-infant physiological synchrony in the context of maternal childbirth-related posttraumatic stress symptoms (CB-PTSS) remains unknown. This study aimed to investigate physiological synchrony within the context of CB-PTSS. Additionally, it investigated the association between mother-infant physiological and behavioral synchrony.

Method

A total of 86 French or English-speaking mothers and their term infants participated. Maternal CB-PTSS was assessed using the PTSD Checklist for DSM-5 (PCL-5) modified for childbirth. Mother-infant dyads were classified into groups based on their responses to the PCL-5. During interactions, physiological synchrony was measured using heart rate variability (HRV), while behavioral synchrony (reciprocity) was observed in video recordings. Dyads' physiological synchrony were classified into negative (opposite HRV fluctuations) and positive (same HRV fluctuations).

Results

Physiological synchrony was observed between mothers and their infants for negative dyads (β=-0.029, p=.033). Coefficient distributions were not significantly different between CB-PTSS groups in positive ($F(2, 37)=2.08$, p=.14) and negative dyads ($F(2, 37)=0.89$, p=.42). No significant associations between physiological and behavioral synchrony in the positive dyads ($F(1, 33)=1.76$, p=.19), or in the negative ones ($F(1, 34)=0.06$, p=.80) were found.

Limitations

Cross-sectional design limits exploring the association between physiological and behavioral synchrony over time within the context of maternal CB-PTSS.

Conclusions

Although we did not find differences in physiological synchrony between groups and observed no association between behavioral and physiological synchrony, our findings suggest there was mother-infant physiological synchrony. Further similar studies controlling for individual physiological regulation, maternal anxiety, and maternal depression are recommended.

Keywords: Physiological synchrony, behavioral synchrony, heart rate variability, traumatic childbirth, reciprocity, interactions.

Title Page (with Author Details)

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Declaration of Interest Statement

Conflict of interest

The authors declared no potential conflicts of interest. Antje Horsch is on the management board of COST Action 22114.

Author Statement

Contributors. S. Devita, N. Messerli-Bürgy, V. Sandoz, and A. Horsch conceptualized the study. A. Lacroix performed the data analysis. S. Devita, C. Deforges, and V. Sandoz collected the data. S. Devita, L. Bozicevic, and V. Sandoz coded the behavioral synchrony data. V. Rattaz helped interpret the heart rate variability data. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work. A. Horsch is the PhD supervisor of S. Devita. V. Sandoz and J. François Tolsa are the co-supervisors of S. Devita.

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1. Introduction

Childbirth-related posttraumatic stress disorder (CB-PTSD) has been proposed as a sub-type of PTSD (Horesh, Garthus-Niegel, & Horsch, 2021; Horsch et al., 2024). As in PTSD, according to the Diagnostic and Statistical Manual of Mental Disorders – 5th Ed (DSM-5), CB-PTSD consists of four symptom clusters: re-experiencing, avoidance, negative cognition and mood, and hyperarousal (American Psychiatric Association, 2022). Childbirth-related posttraumatic stress symptoms (CB-PTSS) characterize instances in which CB-PTSD symptoms, although not meeting diagnostic criteria, interfere with daily life and functioning (Ayers et al., 2023; Horesh et al., 2021). A systematic reviewd showed that the prevalence of CB-PTSS was 12.3% worldwide, although studies mostly involved developed countries (Heyne et al., 2022). Recent research showed that CB-PTSS can be divided into birth-related symptoms (BRS, e.g., reexperiencing, avoidance) and general symptoms (GS, e.g., negative cognition and mood, hyperarousal) (Ayers, Wright, & Thornton, 2018; Sandoz et al., 2022).

A recent meta-analysis found that CB-PTSS are associated with poorer mother-infant relationship quality (Frankham, Thorsteinsson, & Bartik, 2023). During mother-infant interactions, dyadic synchrony can usually be observed. Dyadic synchrony is defined as joint and common navigation of moment-by-moment interactions between the mother and infant, where they coordinate their behaviors and physiological patterns in a smooth and on-line way, responding to each other's cues and signals in a coordinated manner (Provenzi, Scotto di Minico, Giusti, Guida, & Müller, 2018). Physiological synchrony can be observed as the heart rhythms of mothers and infants adapt and coordinate with each other within less than a onesecond lag during interactions in healthy dyads (Feldman, Magori-Cohen, Galili, Singer, & Louzoun, 2011; Nguyen, Abney, Salamander, Bertenthal, & Hoehl, 2021). Meanwhile, motherinfant behavioral synchrony can be measured through emotional expressions, gaze, touch, vocalizations, and reciprocal adaptation (Leclere et al., 2014).

Mother-infant physiological and behavioral synchrony during interactions were identified as a protective factor in infant development, improving infant vagal activity and facilitating better biological rhythm and more optimal infant self-regulation during the first years of life (Abney, daSilva, & Bertenthal, 2021; Feldman, 2007, 2012). Studies suggest a potential bidirectional association between physiological and behavioral synchrony, where disruption in one may be linked to poorer coordination in the other (Davis, West, Bilms, Morelen, & Suveg, 2018; Woody, Feurer, Sosoo, Hastings, & Gibb, 2016). However, one study in mother-infant dyads with and without depression found differences in behavioral synchrony, despite observing no differences in their physiological synchrony (Field, Healy, & LeBlanc, 1989). So far, data is lacking regarding physiological synchrony in the context of CB-PTSS.

Heart rate variability (HRV) is considered as an important indicator of physiological regulation to assess overall wellbeing, including in infants (Oliveira et al., 2019). HRV is one of the markers of the autonomic nervous system that measures the oscillations between consecutive instantaneous heart rates and oscillation intervals of the adjacent QRS complex, which signifies ventricular depolarization due to an electrical impulse (Kranjec, Beguš, Geršak, & Drnovšek, 2014). HRV reflects vagal tone activity, which is known to be an indicator of emotion regulation functioning (Ahemaitijiang, Ren, Wang, & Han, 2021 ; Feldman et al., 2011; Smith, Jones, Charman, & Wass, 2021). Vagal activity is defined as the activity in the vagus nerve that consists of afferent (sensory) and efferent (motor) fibers that stimulate organs in the body, including the gastrointestinal and cardiovascular system that regulates socioemotional functioning (Chang, Mashimo, & Goyal, 2003).

In adults and infants, high HRV is generally related to positive health outcomes (Porges, 2009). On the other hand, reduced HRV has been linked to poorer health outcomes because it indicates autonomic dysfunction (Wulsin, Horn, Perry, Massaro, & D'Agostino, 2015). Moreover, studies in adults found that lower HRV is related to mental health problems (Benjamin et al., 2021; Hartmann, Schmidt, Sander, & Hegerl, 2019). A systematic review found that mothers with depression showed lower HRV compared to healthy mothers (Hamilton & Alloy, 2016). Further, infants of mothers with higher stress levels or previous depression had lower HRV compared to infants born to mothers without a history of depression and with less stress (Jacob, Byrne, &

Keenan, 2009). Not only in depressed mothers, lower HRV is also associated with other psychopathologies including anxiety and somatic distress (Cheng, Su, Liu, Huang, & Huang, 2022; Huang, Cheng, & Liao, 2022). However, to date, HRV in the context of maternal CB-PTSS has not been investigated so far.

Little is known about mother-infant physiological synchrony in high-risk populations (e.g., mothers with mental health problems). Some studies were conducted in mothers with depression. For example, a study by Field et al. (1989) found there was no difference in their heart rate synchrony between mother-infant dyads with maternal depression and no depression, (Field, Healy, & LeBlanc, 1989). Another study of dyads with maternal history of major depressive disorder found discordance of physiological synchrony compared to non-depressed dyads (Woody, Feurer, Sosoo, Hastings, & Gibb, 2016). However to date, no studies have been conducted in the context of CB-PTSD.

So far, to the best of our knowledge, there are no studies that examined the mother-infant physiological synchrony in the context of maternal CB-PTSS. Furthermore, it is unknown if there are associations between behavioral and physiological synchrony in this context. This study investigated if there is physiological synchrony between maternal HRV and infant HRV during social interactions in the context of CB-PTSS at six months postpartum. We hypothesized there was mother-infant HRV synchrony and that HRV synchrony was different between CB-PTSS groups: non-symptomatic (NS), BRS, and GS (hypothesis 1). The second aim was to investigate the association between mother-infant physiological and behavioral synchrony. We hypothesized there was association between mother-infant physiological and behavioral synchrony (hypothesis 2).

2. Methods

2.1 Participants

The project was approved by the local ethics committee (2022-00716). Given that no study had yet investigated the mother-infant HRV synchrony in the context of CB-PTSS, the effect size could not be determined a priori. Comparable to a study investigating mother-infant HRV synchrony in the context of healthy dyads (Feldman et al., 2011; Field et al., 1989; Smith et al., 2021), we collected data from 86 mother-infant dyads. Data of 28 mother-infant dyads came from the control group of a randomised controlled trial on the prevention of CB-PTSS (NCT 03576586) (Sandoz et al., 2019). A further 58 dyads were recruited after that to have a large enough sample size. All data were collected at six months postpartum. We included French- and English-speaking mothers who gave birth to a live baby, at the gestational age of 37 weeks or more, and gave written consent. Exclusion criteria were no sufficient French or English language skills to participate, current psychotic illness, intellectual disability, severe illness of mothers or infants, alcohol abuse, or illegal drug use during pregnancy.

2.2 Procedure

Advertisement for the study was disseminated at maternity hospitals and through contact with daycare centers, gynecologists, and pediatricians in a Swiss canton. Furthermore, we posted the advertisement on the website of a Swiss University Hospital and on social media platforms including Instagram, Facebook, and LinkedIn. After potential participants contacted us, we checked their eligibility and gave them further explanations about the research project, including the purpose of the study, the steps and procedures involved, risks and benefits of the study, the approximate duration of the study, and explained that study participation was voluntary. Mothers who agreed to participate then signed the informed consent form for their own participation and that of their infant.

At six months postpartum, participants were asked to complete online maternal self-report questionnaires (using the Research Electronic Data Capture (REDCap) software) (Harris et al., 2009). The questionnaire assessed maternal CB-PTSS, medical, and sociodemographic data. One week or less after completing the online questionnaire, an appointment was made at the participant's home or at the university hospital, depending on the participant's availability. Mothers were asked to play with their infants as they would do at home for 15 minutes with a standardized set of toys provided by the researchers. Interactions were filmed and both mothers' and infants' heart rates were recorded using a Firstbeat Bodyguard 2 device (Firstbeat Technologies).

2.3 Instruments

Maternal CB-PTSS were measured with the PTSD Checklist for DSM-5, a 20-item self-report questionnaire assessing PTSS over the past month (Weathers et al., 2013), indicating childbirth as the index traumatic event.

Participants responded using 0 (not at all) to 4 (extremely) Likert scale, with a higher score indicating more severe maternal PTSS (Weathers et al., 2013). The
French version of the PCL-5 showed strong validity (Ashbaugh, Houle-Johnson, Herbert, ElHage, & Brunet, 2016).

Mother-infant dyads were divided into three groups based on the maternal responses on the PCL-5. Re-experiencing and avoidance together were classified as BRS, e.g., repeated, disturbing, and unwanted memories of the recent childbirth. Meanwhile, negative cognition and mood, and hyperarousal were classified as GS, e.g., loss of interest in activities that the mother used to enjoy (Ayers et al., 2018; Sandoz et al., 2022). According to DSM-5, symptoms are counted when they are present as a score of 2 or higher (American Psychiatric Association, 2022). If the mother had a score of 2 or higher on BRS-related items (referring to items 1 through 8 and 10 to 11) (Weathers et al., 2013), she was assigned to the BRS group. If the mother had a score of 2 or higher for GS-related items (composed of items 9 and 12 through 20) (Weathers et al., 2013), she was assigned to the GS group. If none of the items was scored as 2 or higher, the mother was classified as belonging to the group NS. If a mother's total score on the items corresponding to BRS and GS were the same, she was assigned to the BRS group because one study found that items corresponding to BRS (compared to GS) had a greater impact on infant outcomes (Garthus-Niegel, Ayers, Martini, von Soest, & Eberhard-Gran, 2017).

HRV, as an indicated variable for physiological regulation, was measured with the ECG device, Firstbeat Bodyguard 2 (Firstbeat Technologies). The Firstbeat Bodyguard 2 is a small device which can be attached to the mother’s and infant’s chest by two disponsible electrodes. Maternal and infant HRV was measured during the free-play for 15 minutes, whereof a mid-sequence (at minute three to minute six) was selected for further analysis. There were no restrictions on movements during recording. After recording, we extracted the data and processed it using R v4.3.0 (R Core Team, 2023).

Behavioral synchrony was operationalized as the reciprocity between the mother and her infant during filmed free-play interaction observed by trained coders using the Global Rating Scales (Murray & Karpf, 2000). Reciprocity refers to the level of mutual interaction between mother and infant during play, including communication, joint orientation, cooperative coordination and turn taking (Murray & Karpf, 2000). According to the manual, reciprocity is coded on a Likert scale from 1 (no reciprocity) to 5 (very much reciprocity).

2.4 Statistical analyses

We first resampled the dyads' HRV raw signals measured during the three minutes' interaction into one second window timeframes using HRV values average or interpolation when appropriate, to ensure an even number of measures between the mother and the infant of the same dyad. Out of the 86 dyads in scope, six dyads' time series contained artefacts (i.e., abnormal HRV values) and were disregarded from the analyses. In total, the analyses were carried out on 80 dyads classified into three groups: non-symptomatic (27 dyads), birth-related symptoms (13 dyads), and general symptoms (30 dyads) based on maternal self-report (PCL-5).

To test the physiological synchrony between mothers and infants (hypothesis 1), we used crosslagged correlations at the dyad level, with time-lags limited arbitrarily to 20 seconds, to check whether any particular temporal pattern showed up across dyads. Then we analyzed the dyads time series synchrony using linear mixed effect models with the dyad as random blocking factor, primarily to identify autocorrelation in the mother-infant HRV signals (autocorrelation measures the relationship between a variable's current value and its past values).

The mlVAR R package (Epskamp, Deserno, & Bringmann, 2023) was used to obtain dyads temporal effects, estimated by calculating the regression coefficients obtained by predicting mother (respectively infant) HRV signals at time t from infant (respectively mother) HRV signals at time t-1 and t-2. To minimize the signals' autocorrelations, we approximated the dyads' HRV signals with Autoregressive Integrated Moving Average (ARIMA) models with one autoregressive and one moving average terms (Dean & Dunsmuir, 2016; Feldman et al., 2011). The cross-lagged correlations (with no time-lag) were computed, for each dyad, on ARIMA residuals. Positive and negative distributions were compared and differentiated from a null hypothesis of an average 0 correlation using Kolmogorov-Smirnov tests.

We also compared the HRV signals' cross-correlation (no time-lag) distributions between real and surrogate dyads. The surrogate dyads were made up by combining the HRV signals of a mother of a given dyad and a randomly chosen infant of another dyad. Kolmogorov-Smirnov tests were used to confirm that the mother-infant true dyads' cross-correlations distributions were not drawn from chance. Differences of mother-infant physiological synchrony between CB-PTSS groups were also tested using ANOVA type II and pairwise tests on estimated marginal means with Tukey corrections to account for the unbalanced design of the PLC-5 groups.

Finally, ANOVA type II and pairwise tests on estimated marginal means with Tukey corrections were also used to test the relationship between the mother-infant behavioral and physiological regulation interaction in the context of CB-PTSS (hypothesis 2), using the interaction between the cross correlation coefficients (time-lag 0) and the PCL-5 groups. All the analyses were done using R v4.3.0 running in RStudio v2023.06.0 build 421(R Core Team, 2023; RStudio Team, 2020). We used two-tailed significance, and $\alpha < .05$ for all statistical tests.

3. Results

3.1 Descriptive statistics

The mean age of mothers was 33.45 years (SD=4.15). The majority were married, cohabitating, or in relationships (84.71%, n=72), and 65.88% (n=56) were Swiss nationals. Additionally, 19.77% (n=17) were nulliparous, and 76.47% (n=65) had received university or applied science education. Regarding childbirth, half of the mothers (48.84%, n=42) had vaginal births. Furthermore, 51.16% (n=44) of the infants were female. The median maternal PCL-5 score was 7 (IQR=10). The median gestational week was 40 (IQR=2), with median APGAR score 10 (IQR=1), mean infants' weight of 3373.95 grams (SD=478.24). We had 16 dyads in the BRS group, 38 in the GS group, and 32 in the NS group.

3.2 Mother-infant physiological synchrony (hypothesis 1)

The cross-lagged correlation coefficients' distribution was calculated as the mean of the crosslagged correlation coefficients for all dyads at each time-lag. Each dyad was classified as positive (mother and infant HRV were fluctuating in the same direction) or negative (mother and infant HRV were fluctuating in the opposite direction), depending on the sign of its correlation at time-lag 0. As averaging positive and negative correlation coefficients would have canceled out the resulting distribution and, consequently, hid some potential effects,

we took the decision to treat the posivitively (40 dyads) and negatively (40 dyads) correlated dyads separately, similar to Abney et al. (2021)

The cross-lagged correlation coefficients' distribution graph (Fig. 1) shows a correlation optimum for the positively and negatively correlated dyads, suggesting a synchrony between the mother and her infant HRV signals. The positively correlated dyads showed a maximum ($r = 0.146$) at time-lag 2, indicating that, on average, the mothers' HRV signals were leading the infants' HRV signal by 2 seconds. The negatively correlated dyads showed a minimum ($r = 0.155$ at time-lag 0), indicating that on average, neither the mothers', nor the infants' HRV signals were leading or lagging.

Multi-level vector autoregression models were used to analyze the relationships between the mothers' and infants' HRV signals. The network temporal relationships showed that the mothers' and infants' HRV signals, for both positive and negative dyads, were mostly autocorrelated (Table 1). There was a marginaly significant positive effect ($\beta = 0.025$, $p =. 071$) of the mothers' HRV signals at time-lag 1 on the infants' HRV signals for the positive dyads. There was a negative significant effect ($\beta = -0.029$, $p = .033$) of the infants' HRV signal at time-lag 1 on the mothers' HRV signals for the negative dyads.

To eliminate the effects of the auto-correlated part of each signal, we fitted the dyads' HRV signals with Auto Regressive Integrated Moving Average (ARIMA) models, with one autoregressive term and one moving average term, and used the residual parts to compare corresponding cross-correlation coefficients' distributions, at time-lag 0, between positive and negative dyads (Fig. 2). K-S tests showed that the positive and negative ARIMA residuals crosslagged correlation coefficients' distributions were significantly different ($D = 1$, $p < .001$) and significantly different from a null hypothesis of an average 0 correlation ($D = 0.50$, $p < .001$ for the positive dyads, and $D = 0.50$, $p < .001$ for the negative dyads).

In the second set of analyses, we conducted a surrogate test to check whether the crosscorrelation coefficients from empirical dyads came from a statistically similar distribution as coefficients from random pairings of individuals into dyads (Abney et al., 2021). To answer this question, for the positive and negative dyads' groups, separately, we randomly paired an infant from one dyad with a mother from another dyad and estimated the time-lag 0 crosscorrelation coefficient (Fig. 3).

Results showed that the surrogate distribution was, as expected, centered at 0, indicating no correlation. The KS tests revealed that empirical and surrogate distributions were not sampled from the same population for the positive dyads ($D = 0.58$, $p < .001$) nor the negative dyads ($D = 0.45$, $p < .001$), confirming that the mother-infant empirical dyads' cross-correlations' distributions were not drawn from chance.

3.3. Differences of mother-infant physiological synchrony between CB-PTSS groups (hypothesis 1)

Type II ANOVA tests on ARIMA residuals cross-lagged correlation coefficients distributions per PCL-5 classification showed that, for the positive dyads (Fig. 4a), there were no significant mean physiological regulation differences between the PCL-5 groups ($F(2, 37) = 2.08$, $p = .14$). For the negative dyads (Fig. 4b), there were no significant mean physiological regulation differences between the PCL-5 groups either ($F(2, 37) = 0.89$, $p = .42$).

3.4 Mother-infant behavioral and phyiological synchrony (hypothesis 2)

We found no significant main effect for HRV synchrony (physiological synchrony) on reciprocity (behavioral synchrony), neither for the positive dyads ($F(1, 33) = 1.76$, $p = .19$), nor for the negative ones ($F(1, 34) = 0.06$, $p = .80$). We found a significant main effect of the PCL5 groups on reciprocity ($F(2, 33) = 3.58$, $p = .04$). For the positive dyads (Fig. 5a), the reciprocity estimated marginal mean was marginally significantly higher for the GS group compared to the BRS group (estimated marginal mean difference = -0.81, $p = .08$) but not significantly higher compared to the non-symptomatic group (estimated marginal mean difference = -0.56, $p = .11$). The reciprocity estimated marginal mean was not significantly different between the birth-related symptom group compared to the non-symptomatic group (estimated marginal mean difference = -0.25, $p = .79$).

For the negative dyads (Fig. 5b), we did not find any significant main effect of the PCL-5 groups on reciprocity ($F(2, 34) = 1.04$, $p = .36$). The interaction between the PCL-5 group and the HRV was not significant, for both the positive or the negative groups.

4. Discussion

This observational study aimed to firstly explore the synchrony between the mother's and infant's physiological regulation during free-play interactions at six months postpartum, in the context of childbirth-related posttraumatic stress symptoms (CB-PTSS). Secondly, it investigated if mother-infant physiological synchrony during interactions was associated with mother-infant behavioral synchrony.

Our results indicated there was significant physiological (HRV) synchrony between mothers and their infants. This finding is in line with a study by Feldman et al (2011) in healthy dyads that found mothers' HRV and infant's HRV coordinated to each other. We observed in the positive dyads a positive significant effect of the mothers' HRV signal at time-lag 1 on the infants' HRV signal. In negative dyads, a negative significant effect of the infants' HRV signal at time-lag 1 on the mothers' HRV signal was found. This corresponds to findings reported by Feldman et al (2011) that identified a bidirectional influence, where infants' HRV leads to an increase or decrease of mothers' HRV and vice versa. Mother-infant HRV synchrony was also confirmed by our finding that cross-correlations' distributions of mother-own infant dyads and mother-other infant dyads differed significantly (which was also observed by Feldman et al (2011)).

In terms of maternal CB-PTSS, both in positive dyads and negative dyads, physiological synchrony was not significantly different between BRS, GS, and the NS groups. Although none of the studies so far focused on maternal CB-PTSS, previous research on maternal mental health symptoms, such as maternal depression and maternal anxiety, had yielded mixed results (Field et al., 1989; Smith et al., 2021; Woody et al., 2016). In groups of mother-infant dyads with maternal depression and without depression, no difference in their heart rate synchrony was observed (Field et al., 1989). However, another study on dyads with maternal history of major depressive disorder found that dyads with no history of depression showed physiological synchrony, while dyads with a history of major depressive disorder showed discordance (Woody et al., 2016). Meanwhile, in a study on mother-infant dyads with maternal anxiety, higher physiological synchrony was found in dyads with more anxious mothers compared to less anxious mothers, suggesting that more anxious mothers lack the ability to buffer stress and to downregulate their arousal when the overall arousal level of the dyad is high (Smith et al., 2021). Thus, higher physiological synchrony in dyads is not always associated with better maternal mental health.

We observed no significant association between physiological and behavioral synchrony in both positive and negative dyads. Notably, in positive dyads, reciprocity was higher in the GS group compared to the BRS group. As no study has investigated dyads' physiological synchrony in the context of CB-PTSS so far, direct comparisons with previous literature are not possible. Further studies are required to confirm our findings and delve into the mechanisms underlying the association (or lack of) between physiological synchrony and behavioral synchrony

This is the first study to investigate the association between mother-infant's HRV and reciprocity in the context of maternal CB-PTSS during free-play interactions, adding to the literature new knowledge regarding the mother-infant physiological and behavioral synchrony in the context of maternal CB-PTSS. In addition, we applied comprehensive extensive analysis techniques to confirm our findings. While our study provides novel insights, it is not without limitations. Our sample size was relatively small, although it is comparable to previous studies looking into mother-infant physiological synchrony (Feldman et al., 2011; Field et al., 1989; Smith et al., 2021). The cross-sectional design did not allow us to understand the changes of this association between maternal CB-PTSS and mother-infant HRV and behavioral synchrony over time. The generalizability of our findings is limited to mother-infant dyads with term infants. In addition, the lacking association between physiological and behavioral synchrony might have been biased due to individual differences in the capacity for physiological regulation, such as vagal suppression that interacts with dyads' behavioral synchrony (Abney et al., 2021; Busuito, Quigley, Moore, Voegtline, & DiPietro, 2019). The clinical implications of our findings are that mothers may find reassurance in knowing there are no differences in terms of dyads' physiological synchrony in the context of maternal CB-PTSS. This implies that mothers may not need to excessively worry about the potential negative impact of their symptoms on the quality of interactions with their infants, at least at a physiological level. However, it is important to note that further studies are needed to confirm our findings while controlling for possible covariates, including individual differences in the capacity of physiological regulation, maternal anxiety, and maternal depression (Field et al., 1989; Smith et al., 2021).

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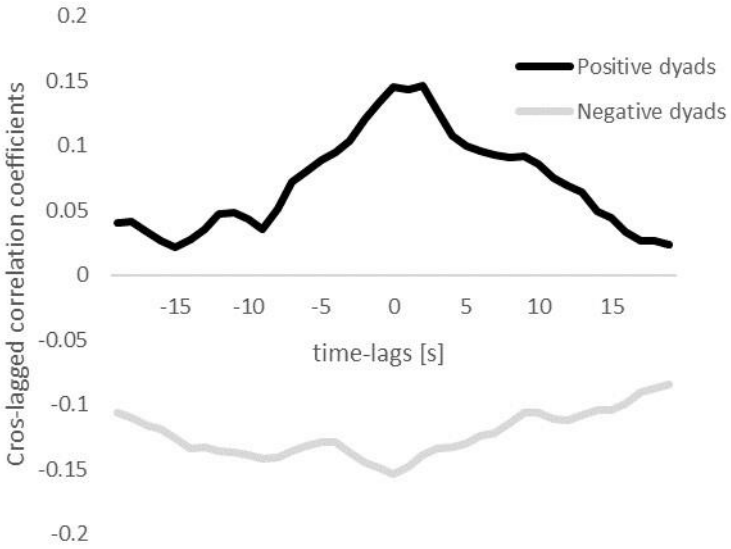
Table 1 Temporal effects.

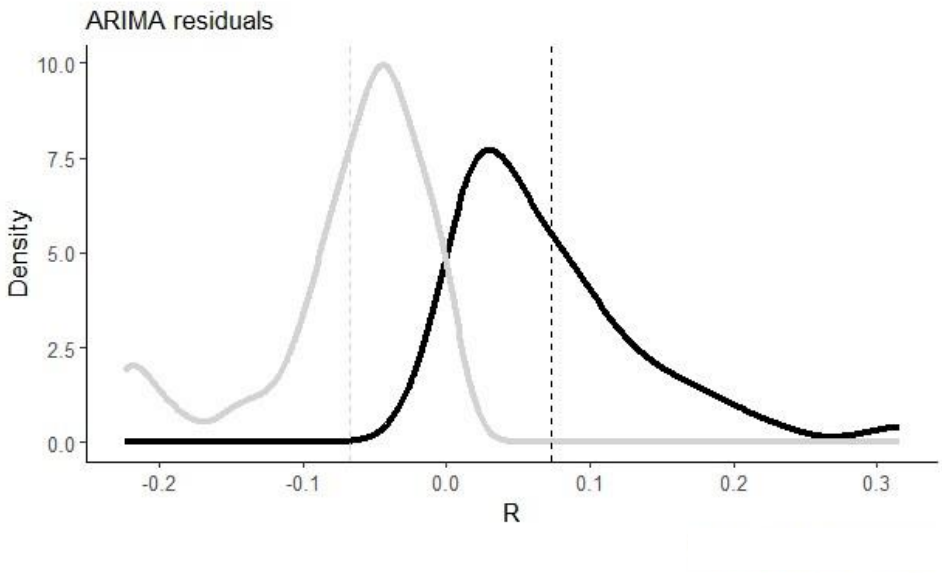
Positive dyads				
	From	To	Time-lag 1	Time-lag 2
	Infant	Infant	0.894, p <.001	-0.135, p <.001
	Mother	Infant	0.025, p=.071	-0.003, p=.797
	Mother	Mother	0.916, p<.001	-0.179, p<.001
	Infant	Mother	0.012, p=.474	0.023, p=.217
Negative dyads				
	From	To	Time-lag 1	Time-lag 2
	Infant	Infant	0.967, p <.001	-0.151, p <.001
	Mother	Infant	-0.016, p=.172	-0.008, p=.481
	Mother	Mother	0.971, p<.001	-0.222, p<.001
	Infant	Mother	-0.029, p=.033	0.002, p=.903

Figure 1
Cross-lagged correlation coefficients' distribution



Positive time-lags: mother is leading, negative time-lags: infant is leading

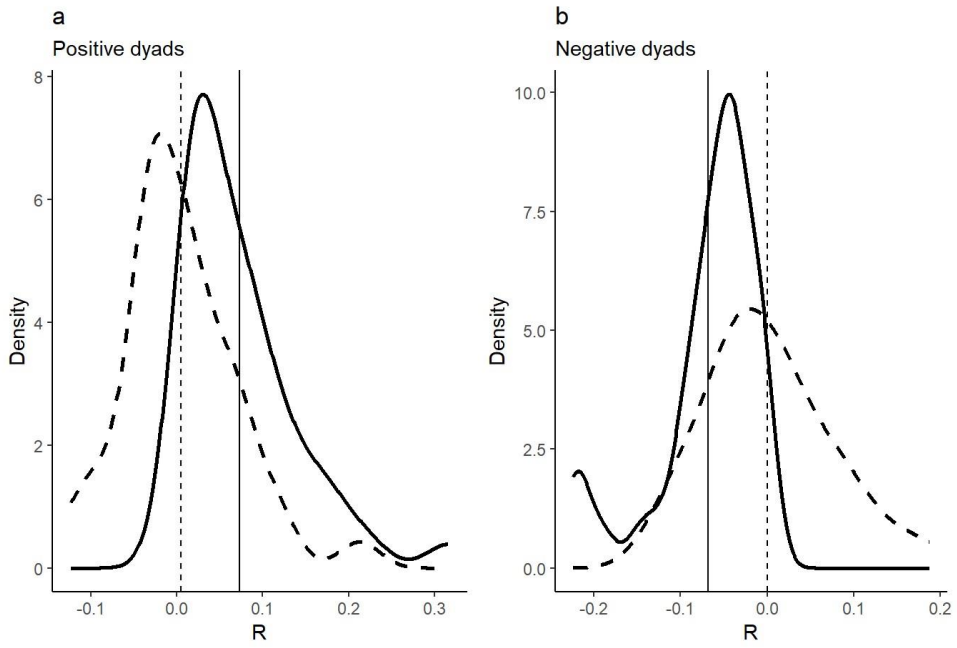
Figure 2
ARIMA residuals cross-lagged correlation coefficients' distributions



Black line: positive distribution, light grey line: negative distribution; vertical dotted lines: distribution means; R: cross-lagged correlation; Density: kernel density estimate (smoothed version of histogram).

Figure 3

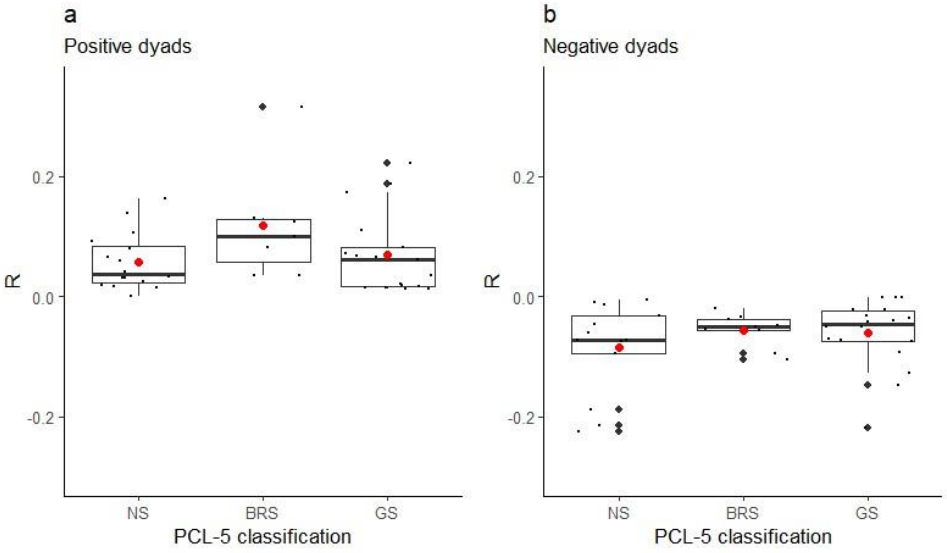
Empirical vs surrogate distributions of positive and negative dyads



Surrogate distribution in dashed line, empirical distribution in solid line; vertical dotted lines: distribution means; R: cross-lagged correlation; Density: kernel density estimate (smoothed version of histogram).

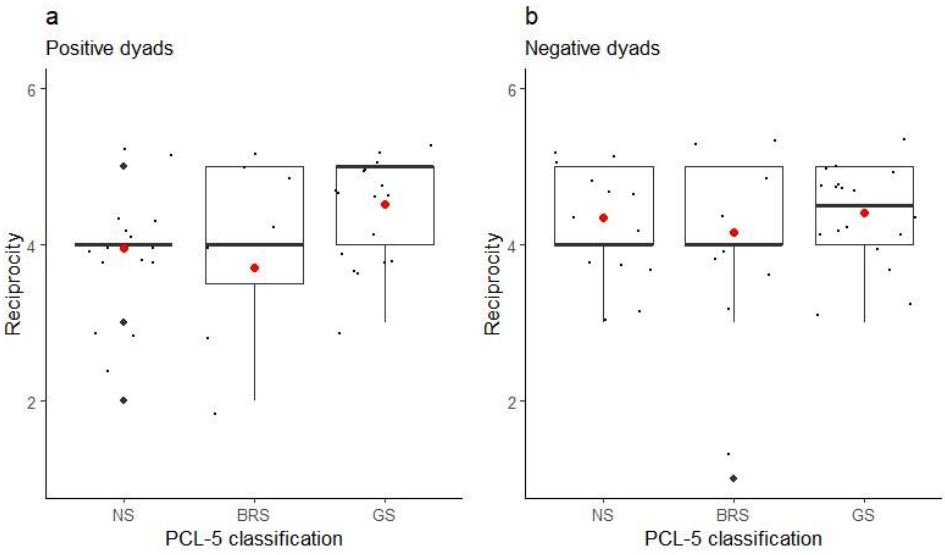
Figure 4

ARIMA residuals cross-lagged correlation coefficients distributions per PCL-5 classification



NS: non-symptomatic; BRS: birth-related symptoms; GS: general symptoms; the distribution estimated marginal means are represented by red dots, the medians by horizontal solid lines.

Figure 5
Group comparison of the reciprocity - HRV coordination relationship



NS: non-symptomatic; BRS: birth-related symptoms; GS: general symptoms; the distribution estimated marginal means are represented by red dots, the medians by horizontal solid lines.

9.6 Appendix F (supplementary materials)

Table 1. Analysis of covariates

Covariates	Outcomes	Significance (p)
Negative infant temperament	Mother-infant bonding t1	0.846
Negative infant temperament	Mother-infant bonding t2	0.970
Positive infant temperament	Mother-infant bonding t1	0.760
Positive infant temperament	Mother-infant bonding t2	0.248
Maternal depression symptoms t1	Mother-infant bonding t2	0.167
Maternal depression symptoms t1	Mother-infant bonding t1	0.005*
Maternal depression symptoms t2	Mother-infant bonding t2	0.192
Maternal anxiety symptoms t1	Mother-infant bonding t2	0.192
Maternal anxiety symptoms t1	Mother-infant bonding t1	0.004*
Maternal anxiety symptoms t2	Mother-infant bonding t2	0.952
Maternal history of trauma	Mother-infant bonding t1	0.670
Maternal history of trauma	Mother-infant bonding t2	0.391
Parity	Mother-infant bonding t1	0.615
Parity	Mother-infant bonding t2	0.364
Infant sex	Infant motor development	0.581
	Infant cognitive development	0.317
	Infant language development	0.689
Apgar	Infant motor development	0.715
	Infant cognitive development	0.076
	Infant language development	0.602
Maternal anxiety symptoms t1	Infant motor development	0.074
	Infant cognitive development	0.744
	Infant language development	0.819
Maternal anxiety symptoms t2	Infant motor development	0.074
	Infant cognitive development	0.491
	Infant language development	0.326
Maternal depression symptoms t1	Infant motor development	0.026*
	Infant cognitive development	0.186
	Infant language development	0.428
Maternal depression symptoms t2	Infant motor development	0.039*
	Infant cognitive development	0.435
	Infant language development	0.314

* p < .05. ** p < .01. *** p <.001.

Table 2. Characteristics of participants

	Total	NS(n=32)	BRS (n=16)	GS(n=38)
Maternal age - mean (SD)	33.45 (4.15)	34.12 (4.10)	31.81 (4.36)	33.57 (4.02)
Civil status - n(%)				
Married/cohabitating/relationship	72 (83.72)	29 (90.62)	14 (87.50)	29 (76.32)
Single	11 (12.79)	2 (6.25)	2 (12.50)	7 (18.42)
Other	2 (2.33)	1 (3.12)		1 (2.63)
Missing values	1 (1.16)			1 (2.63)
Nationality - n(%)				
Swiss	56 (65.12)	22 (68.75)	10 (62.50)	24 (63.16)
European	24 (27.91)	8 (25)	5 (31.25)	11 (28.95)
Non-european	5 (5.81)	2 (6.25)	1 (6.25)	2 (5.26)
Missing values	1 (1.16)			1 (2.63)
Education - n(%)				
University/applied science education	65 (75.58)	24 (75)	12 (75)	29 (76.32)
Apprenticeship	14 (16.28)	4 (12.50)	4 (25)	6 (15.79)
Higher secondary education	2 (2.33)	2 (6.25)		
Secondary education	1 (1.16)	1 (3.12)		
Other	3 (3.49)	1 (3.12)		2 (5.26)
Missing values	1 (1.16)			1 (2.63)
Parity status - n(%)				
Nulliparous	17 (19.77)	7 (21.88)	3 (18.75)	7 (18.42)
Multipara	69 (80.23)	25 (78.13)	13 (81.25)	31 (81.58)
Mode of childbirth - n(%)				
Vaginal births	42 (48.84)	15 (46.88)	9 (56.25)	18 (47.37)
Planned caesarean section	2 (2.33)	1 (3.12)		1 (2.63)
Vacuum-assisted vaginal	5 (5.81)	1 (3.12)	2 (12.50)	2 (5.26)
Forceps delivery	1 (1.16)	1 (3.12)		
Unplanned cesarean section	36 (41.86)	14 (43.75)	5 (31.25)	17 (44.74)
Infant gender - n(%)				
Girls	44 (51.16)	17 (53.12)	10 (62.50)	17 (44.74)
Boys	42 (48.84)	15 (46.88)	6 (37.50)	21 (55.26)
Infant birthweight (gram) - mean (SD)	3373.95 (478.24)	3313.75 (453.18)	3432.18 (583.57)	3400.13 (458.24)
APGAR - median (IQR)	10 (1)	9 (1)	9 (1)	10 (1)
Gestational week - median (IQR)	40 (2)	39.70 (2.10)	40.45 (1)	40 (1.57)
Maternal PCL-5 score - median (IQR)	7(10)	2 (2.25)	10.50 (4)	11.5 (11)

NS: non-symptomatic; BRS: birth-related symptoms; GS: general symptoms; the distribution estimated marginal means are represented by red dots, the medians by horizontal solid lines.

9.7 Appendix G (publication list)

Published articles in peer reviewed journals.

1. Devita, S., Deforges, C., Bickle-Graz, M., Tolsa, J.-F., Sandoz, V., & Horsch, A. (2023). Maternal childbirth-related posttraumatic stress symptoms, bonding, and infant development: a prospective study. *Journal of Reproductive and Infant Psychology, 23,* 1-15 doi:10.1080/02646838.2023.2261057.

Articles under review in peer-reviewed journals.

1. Devita, S., Messerli-Bürgy, N., Lacroix, A., Deforges, C., Bozicevic, L., Rattaz, V., Tolsa, J-F., Sandoz, V., & Horsch, A. (2024). Mother-infant physiological and behavioral synchrony in the context of childbirth-related posttraumatic stress symptoms. *Journal of Affective Disorders*, under review.

2. Devita, S., Bozicevic, L., Deforges, C., Ciavarella, L., Tolsa, J-F., Sandoz, V., & Horsch, A. (2024). Early mother-infant interactions within the context of childbirth-related posttraumatic stress symptoms. *Journal of Affective Disorders*, under review.