Year : 2021

Maternal, partner, and infant health outcomes following traumatic childbirth

Sandoz Vania

Sandoz Vania, 2021, Maternal, partner, and infant health outcomes following traumatic childbirth

Originally published at : Thesis, University of Lausanne

Posted at the University of Lausanne Open Archive http://serval.unil.ch
Document URN : urn:nbn:ch:serval-BIB_680CE66268908

UNIL | Université de Lausanne
Faculté de biologie et de médecine

Institut universitaire de formation et de recherche en soins (Université de Lausanne) en collaboration avec le Département femme-mère-enfant (Centre hospitalier universitaire Vaudois)

Maternal, partner, and infant health outcomes following traumatic childbirth

Thèse de doctorat ès sciences de la vie (PhD)

présentée à la

Faculté de biologie et de médecine
de l'Université de Lausanne

par

Vania SANDOZ

Psychologue diplômée de l'Université de Fribourg.

Jury

Prof Philippe Conus, Président
Prof Antje Horsch, Directrice de thèse
Prof Jean-François Tolsa, Co-directeur de thèse
Prof Susan Garthus-Niegel, Experte
Dre Juliane Schneider, Experte

Lausanne
(2021)

UNIL | Université de Lausanne
Faculté de biologie et de médecine

Ecole Doctorale
Doctorat ès sciences de la vie

Imprimatur

Vu le rapport présenté par le jury d'examen, composé de

Président·e	Monsieur	Prof.	Philippe	**Conus**
Directeur·trice de thèse	Madame	Prof.	Antje	**Horsch**
Co-directeur·trice	Monsieur	Prof.	Jean-François	**Tolsa**
Expert·e·s	Madame	Prof.	Susan	**Garthus-Niegel**
	Madame	Dre	Juliane	**Schneider**

le Conseil de Faculté autorise l'impression de la thèse de

Madame Vania Myriam Sandoz

Master en psychologie, Université de Fribourg, Suisse

intitulée

Maternal, partner, and infant health outcomes following traumatic childbirth

Lausanne, le 11 octobre 2021

pour le Doyen
de la Faculté de biologie et de médecine

Prof. Philippe Conus

Declaration of original authorship

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

Vania Sandoz

2nd of August 2021

Acknowledgements

Much like a mother would do with their infant, the time to submit my PhD thesis has finally come. An African proverb says: it takes a village to raise a child. This echoes very accurately this thesis. To the many people of my village, I do not have enough words to express my boundless gratitude for the unconditional love and support you gave me throughout this journey.

First of all, I would like to thank the Swiss National Science Foundation for the financial support of this PhD. In addition, although I am afraid I cannot express all the gratitude I feel, I want to address my sincere thanks to you, Prof Antje Horsch. You have supported and guided me since day 1, and I could not have dreamt of a better mentor. My inner researcher feels very lucky to have developed by your side, while the human that I am is indebted to you to have been surrounded by your empathy, kindness, and sensitive supervision for all these years. You also transmitted to me the passion for perinatal research, and I hope we will continue making discoveries together. Thanks a million for everything.

I also address my profound gratefulness to you, Prof Jean-François Tolsa, for accepting to co-supervise my PhD. I have greatly appreciated your enthusiasm for my research, as well as your helpful feedbacks. I will keep the image of you, at the beginning of your career, playing Tetris after hard days at work. I hope therefore to never forget that everyone starts from the bottom, in order to always encourage myself to pick up new professional challenges. Moreover, I sincerely thank Prof Susan Garthus-Niegel, Dr Juliane Schneider, and Prof Philippe Conus for accepting to be part of my thesis committee. I was very touched by your friendly, but professional, support and comments, which significantly contributed to the success of my PhD.

Also, it was an honour and a pleasure to complete my PhD at the *Lausanne Perinatal Research Group*. I have met very inspiring and passionate researchers and students. I am grateful for the lovely time we had together. The daily contribution of each of my colleagues should be strongly acknowledged, since they allow the projects to be run perfectly. More specifically, I thank Anna Favero, Annabelle Reuse, Camille Palombo, Cassie Pernet, Céline Piffaretti, Cléo Huguenin-Virchaux, Daniela Barros Rodrigues, Eva Galera, Lara Detoledo, Lara Schütz, Laureline Besuchet, Margot Gafsou, Marion Decaillet, Mathilde Duroux, Mélanie Hausser, Miriam Fergnani, Sebara Gashi, Thaïs Sajin, Valérie Avignon, Yasmina Lotfi, and Yasmina Mabrouk. In addition, I address my sincere gratitude to you, Alain Lacroix, for conducting most of the statistical analyses, as well as the unlimited energy you exerted to make me understand statistics, and the patience you showed in doing so. I am also very thankful to you, Magali Quillet Diop, for your kindness and the professionalism you adopted. Collaborating with you was an enormous pleasure. It was also nice to share the ups and downs of a PhD with both of you, Dr Leah Gilbert and Camille Deforges, and I am delighted about our fruitful research collaborations. My heart also goes out to Dr Suzannah Ravenscroft/Stuijfzand, who was an example both as a researcher and as a mother. I cannot express how much I wish we could celebrate this together. Thank you for being always positive, supportive, and comprehensive. I owe you a lot.

Additional thanks must be addressed to each parent and infant who participated in the projects relating to this thesis. Although we conduct research with the primary aim to help you, I am aware that the birth of a baby means you have little time, however I highly appreciate the energy you invested to complete endless and sometimes weird questionnaires. My gratitude also goes to each healthcare professional from the maternities of Lausanne University Hospital and the Geneva University Hospital, who made it possible for the studies to be run. You do a great job on a daily basis and I know that you always do your maximum to provide the best to families. I am also grateful to Sandrine Estoppey Younes for her precious help regarding saliva samples handling, as well as to Prof Nadine Messerli-Bürgy and Dr Myriam Bickle Graz for their wise advice and comments during our joyful collaborations. To Céline Favrod and Karine Perretten, who knew me as the "baby" intern, I feel very thankful for our friendly moments that helped me to go through this journey.

I cannot end my acknowledgments without paying tribute to my French-speaking friends and family. En premier lieu, je souhaite remercier Quentin et Nicolas pour votre relecture, mais aussi pour votre gentillesse, votre intérêt, et votre joie de vivre. Je vous en dois définitivement une. Elodie et Laura, je me remémore le chemin parcouru depuis Regina Mundi, et quelle aventure! A vos côtés, je suis passée d'étudiante à psychologue, et j'en ai adoré chaque moment. Je me sens si chanceuse de partager cette passion avec vous, et votre enthousiasme et soutien m'ont toujours réchauffé le cœur. Elsa, Maïté, Malvina, Shannon, Océane, Tessa, et Vania, merci pour notre amitié. Vous m'avez portée pendant cette thèse, et j'espère pouvoir vous rendre au moins le centième de ce que vous m'avez donné par votre présence, votre empathie, et votre compréhension. Je nous souhaite encore beaucoup de rires, de célébrations devant le Cervin, et de sororité.

Papa, Maman, simplement merci pour tout : merci pour votre soutien, merci pour votre générosité, et surtout, merci pour votre amour. Laura et Alessandra, vous et vos familles avez été une des motivations premières pour mes recherches. Les familles méritent le meilleur lors de la naissance de la parentalité, et j'espère avoir pu, avec beaucoup de modestie, amener ma pierre à l'édifice. A Lia, Clea, et Léon, j'espère que, si votre souhait un jour est d'agrandir la famille, la recherche aura permis à ce que votre transition à la parentalité soit douce. Cette thèse vous est dédiée. Enfin, Antoine il n'y a rien que je ne puisse dire que tu ne saches déjà. Je te remercie pour ton amour et ton soutien infaillible. Chaque matin au réveil, je savoure la chance d'avoir croisé ta route et de t'y accompagner depuis toutes ces années. Ainsi, peu importent les futures directions de notre chemin, l'important sera de s'y balader main dans la main.

Thesis abstract

Aims: This thesis aimed to address important gaps in the scientific literature regarding the aftermath of traumatic childbirth on maternal, partner, and infant health outcomes, by 1. testing the effects of an early maternal behavioural intervention (visuospatial task procedure) on family health outcomes, via a randomised controlled trial protocol (Study 1); 2. validating the *Lausanne Infant Crying Stress Paradigm* (LICSP) as a standardised stress paradigm within a maternity context and comparing psychophysiological stress responses of mothers at low *vs.* high risk of childbirth-related post-traumatic stress disorder (CB-PTSD), via an experimental cross-sectional study (Study 2); and 3. studying associations between maternal mental health symptoms (i.e., postpartum depression, anxiety, and CB-PTSD) and infant sleep (i.e., night waking and nocturnal sleep duration), via an online cross-sectional study (Study 3). **Methods:** For Study 1, the primary outcome (i.e., maternal CB-PTSD symptoms at 6 weeks postpartum) will be compared within experimental and attention-placebo control participants (n = 144) following an emergency caesarean section. Secondary and other outcomes consist of other maternal and partner psychological and physiological outcomes, parent-infant interaction, and infant developmental and physiological outcomes. For Study 2, we examined the time and group effects on psychophysiological stress reactivity (i.e., salivary cortisol, heart rate variability, and perceived stress) of mothers at low *vs.* high risk of CB-PTSD (n = 52) in response to the LICSP. The low-risk participants were not traumatised after birth whereas the high-risk mothers were traumatised after birth, based on two screening questions assessing the maternal perceived life threat for herself and/or the infant. Study 3 collected maternal mental health and infant sleep data in French-speaking mothers of 3-to-12-month-olds (n = 410), and mediation and moderation effects were tested. All study outcomes were measured via standardised self-report questionnaires, clinical interviews, physiological measures, or behavioural testing. **Results:** Data collection of Study 1 is still ongoing. Study 2 validated the LICSP (time effect) and mothers at CB-PTSD risk showed altered psychophysiological stress responses compared to low-risk mothers, when taking into account the infant perceived life threat during childbirth (group effect). Study 3 found negative associations between maternal mental health symptoms and infant nocturnal sleep duration. Only postpartum depression and anxiety symptoms were associated with infant night waking. Among the three data-driven extracted maternal mental health symptom profiles (i.e., the *depressive*, *anxious*, and *birth trauma* profiles), only the associations between the depressive or anxious profiles and infant sleep were mediated by maternal perception of infant temperament at some particular infant ages and maternal educational levels (moderator effects). The method to fall asleep did not mediate the maternal mental health symptom profiles to infant sleep associations. **Clinical implications:** If results of Study 1 are conclusive, current clinical guidelines for traumatised mothers will change. Results of Study 2 form the first steps in identifying mothers susceptible to develop CB-PTSD with their early stress responses, leading to important clinical implications for early screening of mothers who need professional support. Study 3's findings show the relevance of considering maternal symptomatology and infant perception when infant sleep problems are reported. This thesis therefore supports the importance of considering mothers, partners, and their infants as interconnected components of a system. Future research should extend the focus of maternal mental health to the family context (i.e., both parents and their infant).

Résumé de la thèse

Objectifs: Cette thèse visait à combler certaines lacunes de la littérature concernant les conséquences de l'accouchement traumatique sur la santé des mères, des partenaires, et des bébés, 1. en testant les effets d'une intervention comportementale précoce (procédure de tâche visuospatiale) destinée aux mères, sur la santé de la famille par le biais d'un protocole d'essai randomisé contrôlé (étude 1) ; 2. en validant le *Lausanne Infant Crying Stress Paradigm* (LICSP) comme paradigme de stress standardisé pour le postpartum précoce, et en comparant la réactivité psychophysiologique au stress des mères à faible *vs.* haut risque de trouble du stress post-traumatique lié à l'accouchement (TSPT-A) par le biais d'une étude transversale expérimentale (étude 2) ; et 3. en étudiant les relations entre les symptômes maternels de santé mentale (dépression du postpartum, anxiété et TSPT-A) et le sommeil du bébé (réveils nocturnes et durée du sommeil nocturne) par le biais d'une étude transversale en ligne (étude 3). **Méthodes:** Pour l'étude 1, les symptômes du TSPT-A (résultat principal) du groupe expérimental seront comparés à ceux du groupe contrôle six semaines après une césarienne en urgence (n = 144). Les résultats secondaires incluent d'autres indicateurs parentaux psychologiques et physiologiques, l'interaction parent-bébé, le développement de l'enfant ainsi que certains de ses indicateurs physiologiques. L'étude 2 a examiné les effets du temps et du groupe sur la réactivité psychophysiologique de mères à faible *vs.* haut risque de TSPT-A (n = 52) en réponse au LICSP. Les mères à faible risque n'étaient pas traumatisées par leur accouchement tandis que les mères à haut risque l'étaient, le risque ayant été calculé selon leur réponse à deux questions de dépistage évaluant la menace de mort perçue par la mère pour elle-même et/ou le bébé durant l'accouchement. L'étude 3 a recueilli des informations sur la santé mentale de 410 mères et le sommeil de leur bébé, âgé·e de 3 à 12 mois, et a testé des effets modérateurs et médiateurs. **Résultats:** L'étude 1 est toujours en cours. L'étude 2 a validé le LICSP (effet du temps) et a montré que les réponses de stress psychophysiologiques des mères à risque de TSPT-A étaient altérées comparées aux mères à faible risque, lorsque la menace de mort perçue pour le bébé pendant l'accouchement était contrôlée (effet du groupe). L'étude 3 a observé des associations entre les symptômes de santé mentale maternelle et le sommeil du bébé, sauf pour le TSPT-A et la durée du sommeil nocturne. Trois profils de symptômes de santé mentale de la mère ont émergé des données (les profils *dépressif*, *anxieux* et *lié aux traumatismes de la naissance*). La perception maternelle du tempérament du bébé a seulement agi comme médiateur de la relation du profil dépressif ou anxieux sur le sommeil du bébé, dépendamment de l'âge du bébé ou de l'éducation de la mère (effets modérateurs). La méthode d'endormissement n'a pas médié la relation entre les profils de symptômes maternels et le sommeil du bébé. **Implications cliniques** : Si les résultats de l'étude 1 sont concluants, les directives cliniques pour la prise en charge des mères traumatisées changeront. L'étude 2 fournit des premiers éléments de réponse pour identifier, à terme, les mères à risque de développer un TSPT-A grâce à leur réactivité physiologique afin de leur proposer précocement un soutien professionnel adéquat. L'étude 3 souligne l'importance de considérer la symptomatologie maternelle et la perception maternelle du bébé lorsque des problèmes de sommeil du bébé sont rapportés. Les mères, les partenaires, et leur enfant sont des composants interconnectés d'un système familial, et les recherches futures devraient étendre l'intérêt porté à la santé mentale maternelle au contexte familial (c.-à-d. les deux parents et leur enfant).

Table of contents

I. List of Abbreviations

ANS: Autonomic nervous system

ART ANOVA: Aligned ranks transformation repeated measures analysis of variances

ANCOVAs: Analyses of covariance

C1 to C7: First to seventh salivary cortisol sample collected during the LICSP

CAPS-5: Clinician-Administered PTSD Scale for DSM-5

CB-PTSD: Childbirth-related post-traumatic stress disorder

City BiTS: City Birth Trauma Scale

DSM-5: Diagnostic and Statistical Manual of Mental Disorders, 5th edition

ECS: Emergency caesarean section

EPDS: Edinburgh Postnatal Depression Scale

HADS-A: Anxiety subscale of the Hospital Anxiety and Depression Scale

HF power: High frequency power

HPA axis: Hypothalamic-pituitary-adrenal axis

HRV: Heart rate variability

IBQ-NEG: Negative Emotionality dimension of the Very Short Form of the Infant Behavior Questionnaire-Revised

ICT: Infant crying test

LF power: Low frequency power

LGBTQIA+: Lesbian, gay, bisexual, transgender, questioning, queer, intersex, asexual, pansexual, and allies

LICSP: Lausanne Infant Crying Stress Paradigm

PNS: Parasympathetic nervous system

PTSD: Post-traumatic stress disorder

RCT: Randomised controlled trial

SNS: Sympathetic nervous system

START: Swiss TrAumatic biRth Trial

TSST: Trier Social Stress test

VAS: Visual analogue scale

II. List of Figures

III. List of Tables

1. Introduction

1.1. Traumatic childbirth

Evidence suggests that parental expectations are not necessarily and wholly met during childbirth (1, 2). During labour and delivery, parents may experience negative emotions, such as fear, frustration, helplessness, or terror (1, 3, 4). As a result, about one-third of mothers appraises their childbirth as traumatic in populations with and without medical complications (2, 5, 6). Furthermore, 60% of fathers[1] experience the childbirth as distressing (4).

According to the post-traumatic stress disorder (PTSD) criterion A of the Diagnostic and Statistical Manual of Mental Disorders 5th edition (DSM-5), a traumatic event corresponds to a direct or indirect "*exposure to actual or threatened death, … [or] serious injury*" (p. 271, 7). Given that it can involve a threat to the life or the physical integrity of the mother and/or her infant, childbirth can fulfil the PTSD criteria A of the DSM-5 (7). Whether childbirth is perceived as traumatic firstly depends on the parental subjective appraisal of the event (8-10). Both scientific evidence and clinical observations argue that an objectively standard childbirth, as described by maternity healthcare professionals, may subjectively be perceived as traumatic by parents (3, 9, 11). Following traumatic childbirth, both parents can develop mental health difficulties, such as symptoms of childbirth-related PTSD (CB-PTSD) (9, 12-16).

1.2. Consequences of traumatic childbirth on parental mental health outcomes

1.2.1. Childbirth-related post-traumatic stress disorder

PTSD is a mental health disorder that develops after a traumatic stress exposure (i.e., PTSD criterion A). Symptoms are categorised into four DSM-5 clusters (7) :

1. *Intrusions* (PTSD criterion B, one symptom required), i.e., involuntarily traumatic intrusive memories specific to the event, such as flashbacks or nightmares of the corridor lights leading to the operating theatre;
2. *Avoidance of trauma-related cues* (PTSD criterion C, one symptom required), i.e., persistent avoidance of stimuli associated with the trauma, such as avoidance of the hospital or avoidance of talk of the birth;
3. *Negative cognitions and mood* (PTSD criterion D, two symptoms required), i.e., negative alterations in cognitions and mood, such as anhedonia, low mood, or self-blaming;
4. *Hyperarousal* (criterion E, two symptoms required), i.e., marked alterations in arousal and reactivity, such as increased startle response, excessive hypervigilance towards the infant, or angry outbursts.

PTSD can be diagnosed one month following the traumatic stress exposure (PTSD criterion F, 7), even if an acute post-traumatic stress response can be observed in the meantime (15, 17). Furthermore, a significant distress or impairment of functioning must be present in everyday life (PTSD criterion G, 7). In addition, dissociative symptoms

[1] In this thesis, the term *partner* refers to the male or female co-parent. When studies reported in this thesis included only male partners, the term *father* is used.

may sometimes be experienced, e.g., derealisation and depersonalisation (7). According to the DSM-5, CB-PTSD is not a specific diagnosis (7), although it has recently been proposed as a new subtype of PTSD (18). Clinical characteristics of CB-PTSD and PTSD are slightly different, with a recent study concluding that mothers with CB-PTSD showed more intrusions symptoms than mothers with PTSD related to other stressors (19). Psychometrics studies investigating the latent structure of CB-PTSD identified two symptom clusters: birth-related symptoms (e.g., flashbacks, avoidance) and general symptoms (e.g., low mood, anhedonia, i.e., loss of pleasure or interest)) (20-25). Specific common postpartum factors, such as fatigue or hypervigilance towards the infant, may overestimate CB-PTSD symptomatology (20).

Parents can also suffer from clinically significant CB-PTSD symptoms at a non-diagnostic level (26-29). Subthreshold symptomatology can have deleterious effects on their functioning, which can be intensified with intrusions symptoms (27). In community samples, 3-4% of women meet CB-PTSD diagnostic criteria (30, 31). In high-risk samples, CB-PTSD prevalence rates even increase up to 16-19%, e.g., after an emergency caesarean section (ECS), which has been reported as one of the most traumatic delivery modes (30, 31).

A diathesis-stress model has been proposed for the aetiology of CB-PTSD (5, 32). According to this model, CB-PTSD development is the result of the interplay between vulnerability factors in pregnancy (e.g., antenatal depression, tokophobia), risk factors during birth (e.g., birth experience, operative birth), and postnatal factors (e.g., depression and other comorbid symptoms) (5, 32). Moreover, evidence suggests that mothers with CB-PTSD do not systematically recover spontaneously (33-36).

Fathers' presence during labour and delivery has significantly increased during the last couple of decades (37). Consequently, they are increasingly at risk of developing CB-PTSD symptoms (4, 38). To date, research on paternal CB-PTSD is scarce (13). So far, only a few studies have reported CB-PTSD prevalence rates varying between 0-7% within community samples during the first year postpartum (13, 14, 16, 29, 39, 40). Following the infant's hospitalisation in a neonatal intensive care unit, CB-PTSD prevalence rates from 1%-67% were reported in fathers (29, 41-49). The aforementioned studies differ by their sample size, their population characteristics, as well as their CB-PTSD assessment tools and time points. In addition, to the best of my knowledge, CB-PTSD has only been examined in fathers, and no research has reported prevalence rate in partners.

In conclusion, partners, by witnessing childbirth, can also develop CB-PTSD symptoms. To date, research mostly assessed paternal CB-PTSD in cross-sectional studies with self-reported questionnaires. Longitudinal studies assessing partner CB-PTSD symptoms via clinical interviews, such as the Clinician-Administered PTSD Scale for DSM-5 (CAPS-5), would increase our understanding of the impact of a traumatic childbirth experience on partner health outcomes (50). Also, research investigating the course of partner CB-PTSD and its risk and protective factors is required (51). Thus, research on partner mental health following a traumatic childbirth experience is timely and should be further pursued (13, 51, 52).

1.2.1. Comorbidity of childbirth-related post-traumatic stress disorder

In the postpartum period, the co-occurrence of CB-PTSD, postpartum depression, and/or anxiety symptomology is the rule rather than an exception (7, 10, 53-56). Depression symptoms consist of experiencing for more than one month some of the following symptoms: depressed mood, anhedonia, fluctuation in weight, appetite disturbance, concentration difficulties, sleep disturbance, fatigue, agitation, guilt, and suicidal thoughts (7). Thirteen percent of mothers are affected by postpartum depression within the year following childbirth (57, 58). An important overlap of CB-PTSD and postpartum depression has been described in mothers, with research reporting that 5% to 90% of women suffering from CB-PTSD also experience depression during the year following childbirth (10, 35, 54, 59-62).

According to a meta-analysis, 10% of fathers experience depression during the perinatal period (i.e., the time from conception up to 1 year after childbirth) (63). The most critical period appears to be between 3 to 6 months postpartum, with a prevalence rate of 26% (63). Depression symptoms in mothers and fathers were shown to be concurrently and prospectively associated in the postpartum period, with weak strengths of association ($r = 0.19$ to $r = 0.28$) (64). This supports the World Health Organization's call to involve fathers in perinatal health services to improve maternal and child health outcomes (65).

Less research has been conducted on the co-occurrence of CB-PTSD and anxiety (56). Perinatal research either investigated anxiety symptomatology or anxiety disorders (40, 66, 67). Symptoms of anxiety involve constant worries, tension, avoidance, obsessions, as well as physical changes, whereas anxiety disorders include for instance panic disorder, generalized anxiety disorder, obsessive-compulsive disorder, and phobias (7, 66). According to a systematic review and meta-analysis, up to 15% of mothers experience clinically significant anxiety symptoms during the first 6 months following childbirth (67). Moreover, 9% to 10% of mothers suffer from at least one anxiety disorder in the postpartum period (66, 67). Regarding paternal prevalence, wider ranges were observed, with rates ranging from 2% to 31% for clinically significant anxiety levels over the year following childbirth (40, 68). As for anxiety disorder prevalence, up to 12% of fathers experience an anxiety disorder in the postpartum period (40).

Recently, a longitudinal study reported that 7% of women at 4-6 weeks postpartum and 5% at 6 months postpartum experienced both CB-PTSD and anxiety (54). Moreover, 2% to 3% of mothers had co-existing CB-PTSD, postpartum depression, and anxiety symptoms, according to a systematic review (56). The question arises as to the existence of mechanisms shared by these postpartum-specific comorbidities. A recent study revealed that symptoms of both CB-PTSD and postpartum depression, when excluding their overlapping symptoms (i.e., anhedonia, sleep disturbance, and concentration difficulties), loaded onto a one-factor model explaining 68% of the total variance (10). The authors therefore recommended distinguishing the condition of coexisting CB-PTSD and postpartum depression from CB-PTSD or depression alone, since different risk factors were involved in these conditions (10).

Whether coexisting CB-PTSD and postpartum depression represent a childbirth-related phenotype or an artefact of overlapping symptoms is therefore not clear, even though it has critical treatment implications (69). Indeed, in the case of a childbirth-related phenotype, an evidence-based treatment for PTSD should be effective to treat mothers with symptoms of both CB-PTSD and postpartum depression, whereas with the hypothesis of an overlap of symptoms, different therapeutic approaches would be required (69). How maternal mental health symptoms after traumatic childbirth occur and interact is therefore still to be investigated. This area of research is even less studied in partners and therefore also should be explored. To improve care provided to families following traumatic childbirth, research investigating CB-PTSD, postpartum depression, and anxiety in both mothers and partners over time are paramount to enhance our understanding of parental mental health (51, 56, 66, 67, 69).

1.2.2. Prevention of childbirth-related post-traumatic stress disorder

Given that risk factors of traumatic childbirth are known, primary prevention strategies are of interest (9). Due to the nature of the trauma and the ability to directly access the population after the traumatic event, early interventions to prevent CB-PTSD should be developed (9). Unfortunately, to date, such early evidence-based interventions are lacking (9, 27, 70).

Intrusive memories may be a relevant target for such interventions. Indeed, intrusive memories are a core symptom of PTSD and generally consist of re-experiencing the most distressful moments of the trauma (7, 71-73). Hence, intrusive memories often take the shape of sensory-perceptual images including visuospatial elements (72, 74). It has been suggested that such memories are caused by the predominance of the data-driven processing related to trauma-cue perceptual impressions during the trauma over the conceptually-driven processing, which allows making sense of an event (74, 75). As a result, sensory-based memories associated with the trauma involuntarily intrude into the mind (74, 75). Besides generating significant psychological distress, intrusive memories are a precursor of PTSD symptoms (7, 76). Thus, intrusive memories are thought to be involved in PTSD maintenance and development (72). For instance, experiencing intrusive memories can trigger trauma-related behavioural avoidance (PTSD criterion C), emotional distress (PTSD criterion D), and hypervigilance (PTSD criterion E), causing impairment in everyday functioning (72). Hence, early interventions targeting childbirth-related intrusive memories could prevent subsequent CB-PTSD (27).

It has therefore been postulated that a brief behavioural procedure, including a visuospatial task, occurring 30 minutes after an analogue traumatic event could impede intrusive memories (77). This is based on two main cognitive and neurobiology findings. First, the brain has selective resources with limited capacity, indicating that visuospatial cognitive tasks engage visuospatial resources, which are thus not available for concurrent task (78). Second, memory consolidation, i.e., the time-dependent stabilisation process that transforms recent encoded experiences into long-term memory (79), can be disrupted within the 6 hours following the traumatic event. In other words, memory is malleable during the first 6 post-traumatic hours, which could be a window opportunity for early CB-PTSD interventions (80). Hence, given that intrusions are sensory-perceptual and essentially visual, performing a visuospatial task during the first postpartum hours may compete for visuospatial resources needed for childbirth

memory consolidation (77, 81). In summary, it is assumed that memory is vulnerable to interference during the consolidation window following the traumatic event (80, 82, 83). Playing the computer game Tetris, which is a visuospatial memory resources task (84), whilst memory is undergoing consolidation, could prevent the development of visual traumatic memories (85), causing a decrease of future trauma-related intrusions (77).

Accordingly, an early brief behavioural intervention including the computer game Tetris was tested with healthy individuals when exposed to an analogue traumatic event in laboratory settings (77, 81). Participants who engaged in a visuospatial working memory task (Tetris) 30 minutes to 4 hours following a traumatic film reported a reduced number of intrusive memories during the following week than individuals who performed a verbal task, or performed no task at all, after the event (77, 81). Recent studies showed the importance of memory cue reminders in such intervention (e.g., presentation of images reminding the analogue traumatic event) to guide the interference process to target more specific elements of the memory trace (86-88). It was therefore postulated that this early brief behavioural intervention must include both the following components to be effective: a memory reminder and a visuospatial task (89). In addition, mental rotation was also shown to be an important factor of this behavioural intervention (77). Translating these findings to clinical settings randomised controlled trials (RCTs) showed similar results with patients of an emergency department who experienced a traumatic event (e.g., motor vehicle accident, industrial accident, assault) (86, 90).

To the best of my knowledge, only one proof-of-principle RCT used a similar intervention protocol to prevent intrusive memories following traumatic childbirth (15). Mothers of the intervention group uninterruptedly played the computer game Tetris for 15 minutes within the 6 hours following their ECS in their hospital bed (15). Given that the intervention was delivered in the same context as in which the trauma occurred, no additional memory cue reminder was needed (in contrast to 86, 90). Mothers of the control group received the usual care (15). In comparison with the control condition, the intervention group had a reduced number of intrusive traumatic memories during the first week following the ECS (15). Moreover, at 1 month postpartum, mothers who received the intervention reported lower CB-PTSD symptoms than controls (15). Although being promising, these findings should be replicated with a larger RCT including an active placebo control group, using clinical interviews, and investigating the longer-term effects of the intervention protocol on the whole family.

1.3. Consequences of traumatic childbirth on maternal physiological stress reactivity

1.3.1. Post-traumatic stress disorder and the stress response system

The reasons as to why only some people develop (CB-)PTSD after traumatic stress exposure are not entirely clear (8). Psychobiological evidence suggests that an alteration of the stress response system may play a major role in PTSD development (91, 92). The stress response system is constituted by the sympathetic (SNS) and the parasympathetic (PNS) branches of the autonomic nervous system (ANS), as well as by the hypothalamic-pituitary-adrenal (HPA) axis that is a neuroendocrine cascade response (93). ANS activation in response to stress can be observed with heart rate variability (HRV) parameters, such as high frequency (HF) power, low frequency (LF) power, and LF/HF ratio (93). In response to stress, PNS activation reduces, which is reflected by a decrease of HF

power and, in contrast, SNS activation is enhanced, which is mainly shown by an elevation of LF power (93). As a result, a short-term imbalance of ANS is observed, represented by an elevation of the LF/HF ratio (93). PNS withdrawal leads to increased arousal and attention, whereas the SNS controls the organism's reactions to a perceived threat, and is involved in the "fight or flight" response (i.e., the automatic physiological response to a stressful or frightening event) (93, 94).

After stress exposure, SNS and PNS changes manifest themselves almost immediately, while cortisol release reflecting the HPA axis activation peaks at 10 to 30 minutes post-stress application (94). Cortisol release allows the organism to mobilise psychological and physiological resources and to recover by neutralising the physiological impacts of SNS activation (93). In addition to HPA axis and ANS changes, psychological stress responses, such as perceived stress, are observed following stress exposure (95, 96).

Hormonal changes during pregnancy and in the early postpartum period interact with cortisol release, which is elevated throughout the pregnancy before returning to initial levels at 12-24 hours postpartum (97-99). Furthermore, hormonal activation triggered during breastfeeding can influence the cortisol release, blunting the cortisol response within the hour following breastfeeding (100).

Dysregulated HPA axis activation has been associated with PTSD development and maintenance. In laboratory settings, the stress reactivity of the HPA axis can be measured with the cortisol response to stress paradigms (101-103). Typically, individuals with PTSD or exposed to a traumatic event show mostly blunted cortisol release in response to stress compared to healthy individuals (104-107). Only one study observed increased cortisol responses in women with childhood abuse-related PTSD after being exposed to traumatic memory reminder cues compared to healthy women with a history of childhood abuse (108). Given the small sample size (n = 12 each group) and the use of an unstandardised stress paradigm, these findings must be considered cautiously, especially since all other evidence observed a blunted cortisol stress reactivity following a lab-based stress task (105-107, 109). This blunted cortisol stress reactivity was found in US female war veterans when compared with civilian women, irrespective of their PTSD status (107), in postpartum mothers with emotion regulation problems and a history of child maltreatment (106), and in mothers with interpersonal violence-related PTSD at 1 and 2 years postpartum (109).

Another indicator of a stress response is a low HRV, indicating that the cardiovascular system cannot properly adapt to external and internal demands (92). In response to laboratory stress induction, healthy individuals showed a PNS activation withdrawal (i.e., reduced HF power), and SNS activation and ANS imbalance elevation (i.e., increased LF power and LF/HF ratio) (110-112). According to previous meta-analyses, individuals with PTSD had lower HRV than controls at rest (92, 113, 114). In response to stress exposure, patients with PTSD tended to have diminished PNS activation compared to healthy individuals (114).

To the best of my knowledge, stress reactivity has never been studied in mothers with CB-PTSD, nor following traumatic childbirth. Hence, it is unclear whether altered stress reactivity can already be observed early after trauma exposure when CB-PTSD is not yet present. Investigating early changes to the psychophysiological stress reactivity

in early postpartum mothers following traumatic childbirth could eventually lead, on the one hand, to the identification of CB-PTSD risk factors, and on the other hand, to a better understanding of physiological mechanisms involved in CB-PTSD development (104). Given that no validated lab-based tasks adapted to the early postpartum period exist so far, we developed the *Lausanne Infant Crying Stress Paradigm* (LICSP), a standardised stress paradigm adapted to early postpartum mothers and to the maternity context. Therefore, the following chapter builds on the development of the LICSP and its related theoretical constructs.

1.3.2. The Lausanne Infant Crying Stress Paradigm

The LICSP procedure was inspired by the *Trier Social Stress Test* (TSST) considered as the gold standard stress paradigm to elicit psychophysiological stress responses in adults (101, 103). The standard TSST procedure contains a baseline phase, a stress phase, and a recovery phase (102, 103). During the TSST baseline and recovery periods, participants are instructed to rest while sitting (102, 103). Duration of the baseline and recovery periods depend on the stress reactivity outcomes (103). For example, when assessing salivary cortisol collected at 10-min intervals, the baseline phase lasts 30 min and the recovery phase 70 min (103).

During the TSST stress phase, participants take part in a mock job interview after a 3- to 10-min anticipation period of the aforementioned task (102, 103). Hence, while standing in front of a panel of committee members, they must convince them that they are the perfect candidate for the job during 5 min (102, 103). This psychosocial stressor is followed by a surprise mental arithmetic task of 5 min (i.e., a cognitive stressor) (102, 103). Performing these motivated tasks in front of a panel of experts represents a stressful social-evaluative threat (i.e., when some part of the self is evaluated by others). This threat-related stress is emphasised by the video and voice recording of the performance, by instructions informing participants that the experts are behavioural analysts, and by the panel attitude suppressing any types of social engagement or positive feedback (102, 103). The stress anticipation, the socio-evaluative threat, and the motivated performances (i.e., active personal involvement in a task that is judged and that demands observable or cognitive outcomes) are key evidence-based elements to induce a psychophysiological stress response in adults (101, 103). Besides, the TSST contains other evidence-based stress-inducing characteristics, such as novelty and/or unpredictability, and uncontrollability (101, 103, 115). Indeed, throughout the TSST, participants are not aware of the psychosocial stressor until the anticipation period, and they are surprised by the cognitive stressor, which is unexpected.

The TSST is likely to fail to elicit psychophysiological stress reactivity in early postpartum mothers given physical and psychological restraints, such as the impossibility of standing up during the stress phase or the inadequacy of playing a job interview scenario, as most maternal concerns in the days following childbirth are focused on their infant or motherhood (101, 103, 116). Thus, the LICSP procedure was developed by including the principal components of the TSST with adjustments for the early postpartum period (101, 103, 116). Figure 1 shows the LICSP procedure and time points of measurements.

Participants are asked to rest in their hospital bed with their infant during the LICSP baseline and the recovery phases. The stress phase occurs in a separated consultation room, in presence of an unknown female medical

experimenter, whose role consists of observing participants and providing them with instructions while adopting a neutral facial attitude (103). Participants are filmed throughout the stress phase on the pretext that specialists will analyse their behaviour afterwards. The stress phase starts with a 3-min anticipation period of the infant crying test (ICT) and is followed by the psychosocial stressor, namely the ICT, and then by the TSST cognitive stressor (i.e., the surprise mental arithmetic task) (103). The ICT implicates identifying one's infant crying among several recordings of infant crying. Instructions given to participants imply that mothers can usually identify their infant's crying. The purpose of this is to threaten the maternal social self to induce stress (101, 117). In sum, both the psychosocial and cognitive stressors include the aforementioned main evidence-based properties necessary to elicit psychosocial stress reactivity (101, 103, 115). Finally, to avoid side effects, an optional 8-min guided relaxation is offered at the end of the recovery period (118). Moreover, after the LICSP, a moment to debrief is offered to participants to discuss their experience.

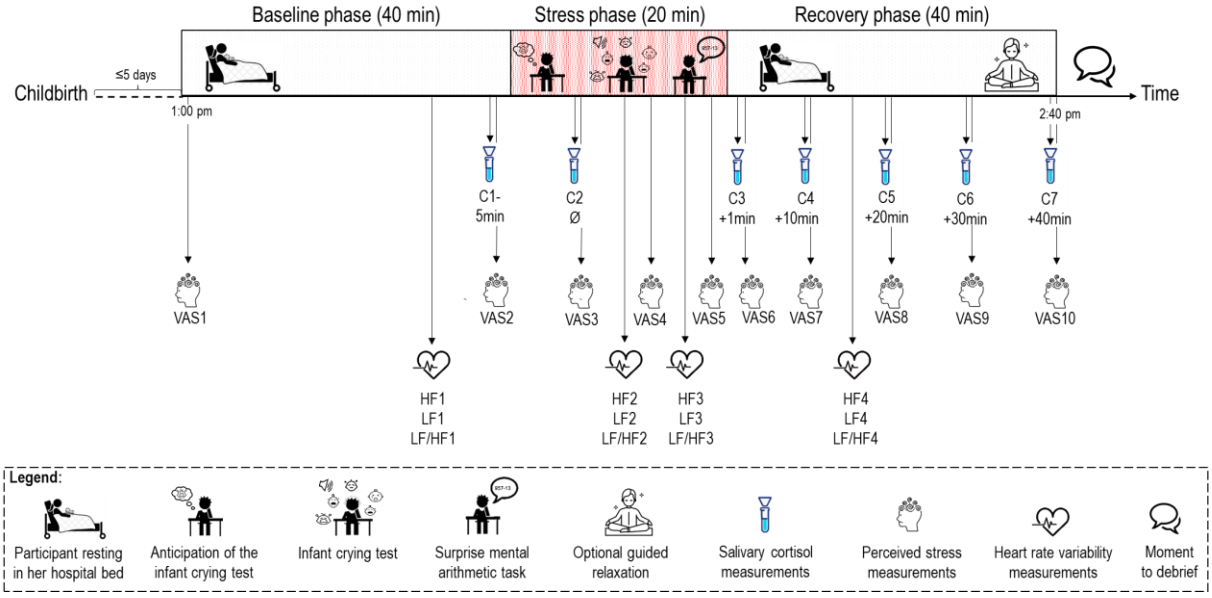


Figure 1. The Lausanne Infant Crying Stress procedure and time points of measurements. Perceived stress is collected via a visual analogous scale (VAS) and heart rate variability measurements includes high-frequency (HF) power, low-frequency (LF) power, and LF/HF ratio.

A shown in Figure 1, the LICSP procedure assesses the HPA axis reactivity via salivary cortisol collected at seven different time points, namely 5 min before the stress phase (C1), directly after the anticipation task (C2), and during the recovery phase at 10 min intervals (C3 to C7) (103). Besides, ANS activity reflected by HF power, LF power, and LF/HF ratio is measured with four 3-min cardiac recordings: one during the baseline, a second during the ICT, a third during the surprise mental arithmetic task, and a fourth during the recovery (110, 112). Finally, perceived stress is assessed at ten different times over the LICSP via a visual analogue scale (VAS) (119).

To investigate psychophysiological stress reactivity of mothers at risk of CB-PTSD shortly following traumatic childbirth and therefore addressing a gap in the literature regarding CB-PTSD development, the LICSP should first be validated as an effective paradigm for mild stress induction adapted to the maternity context. In future studies,

the LICSP could represent a valuable tool to evaluate innovative and early evidence-based interventions that aim to prevent the negative effects of CB-PTSD on mothers, but also on their families (52, 70, 104).

1.4. Consequences of traumatic childbirth on infant health outcomes

1.4.1. The intergenerational transmission of stress and trauma

Traumatic childbirth affects parents, but also their offspring (13, 120-126). In the United Kingdom, almost three-quarters of the estimated economic cost of maternal perinatal mental health was related to adverse impacts on the child rather than the mother, being roughly £6 billion for each one-year birth cohort (127). Hence, offspring outcomes after traumatic childbirth are a public health issue and warrant further investigations.

According to the model of intergenerational transmission of stress and trauma, offspring developmental and biological outcomes can be modulated by parental biological changes after traumatic stress exposure (128). It was postulated that these epigenetic changes occur through three pathways: (1) at preconception where stress modifies the gametes; (2) during pregnancy via stress consequences on the uterine environment and; (3) through early postnatal care where parental biological changes triggered by stress can impede appropriate parent-infant interactions (128). The third pathway is suited to investigate alterations in the offspring's biological system and development due to parental CB-PTSD following traumatic childbirth.

Lately, a systematic review investigating associations between maternal CB-PTSD and child outcomes reported negative associations between CB-PTSD and breastfeeding (129), which is predictive of both maternal and child health outcomes (130). Findings are inconsistent regarding associations between maternal CB-PTSD and child cognitive development, mother-infant relationship, and bonding (52, 121, 129, 131-133). A recent study concluded that, compared to controls before COVID-19, mothers who gave birth during the pandemic reported higher acute stress symptoms after delivery, which in turn was associated with CB-PTSD symptoms and bonding problems (133). Conversely, Nakić Radoš and colleagues observed no association between maternal birth-related symptoms of CB-PTSD and bonding (131). Interestingly, they found that maternal general symptoms of CB-PTSD had a direct effect on bonding and an indirect effect via maternal postpartum depression symptoms (131).

In sum, although more research on the aftermath of traumatic childbirth on infant outcomes is needed, current literature suggests a maternal intergenerational transmission of stress- and trauma-related consequences (128, 129, 134). Intergenerational transmission of stress- and trauma-related consequences also concerns fathers, although research on this is scarce (13, 52, 128). The role of fathers should not be underestimated in this intergenerational transmission, especially via the third pathway (52). Mechanisms involved in this possible paternal transmission of stress- and trauma-related consequences to their offspring are not known yet (52). It was proposed that both parents could influence each other's psychological, physical, and biological states, and subsequently impact child development, e.g., cognitive and sleep outcomes (52). In addition, given that the intergenerational transmission of stress and trauma was postulated to occur via early postnatal care (128), research studying infant outcomes after traumatic childbirth should also include non-biological parents. Hence, research on the

intergenerational transmission of stress- and trauma-related consequences of both mothers and partners, as well as the mechanisms underlying this transfer (i.e., direct or indirect path), is necessary to better understand this third pathway (52).

1.4.2. The consequences of traumatic childbirth on infant sleep

As briefly mentioned above, traumatic childbirth and CB-PTSD can have a deleterious impact on infant outcomes, even though more research is needed. In addition, poor sleep quality during infancy and childhood is predictive of adverse developmental outcomes (e.g., socio-emotional or behaviour problems) (135-137) and is associated with negative family functioning and maternal well-being (138, 139). To the best of my knowledge, the aftermath of traumatic childbirth and CB-PTSD on infant sleep during the first year postpartum has not been examined so far and is, therefore, essential to be explored.

From birth, infant sleep consolidation rapidly develops, with the most significant changes occurring between 1 and 2 months, with a sleep consolidation peak at 3 months (140, 141). From 3 to 12 months, the longest period of continuous sleep without waking is relatively stable, increasing less than 30 minutes between these ages (141). The self-regulated sleep period (i.e., amount of time when infants are either sleeping or are quietly awake) rapidly increases from 1 to 4 months and stays stable until 9 months, before gradually increasing until 12 months (141). Importantly, infants with sleep self-regulation competencies are more likely to sustain sleep for more than 5 or 6 hours (141). Infant acquisition of sleep self-regulation competencies are dependent on environmental factors, such as the method of falling asleep, as reflected by bedtime interactions (142-145).

Sleep problems, e.g., short night sleep duration and night waking, concern 10% to 17% of infants (146, 147). Only 30% of sleep problems seem to have physical causes at ≤5 years old, suggesting sleep problems may be related to parental behaviour (148). Maternal parenting at night was for example associated with infant night waking (138), supporting that specific maternal behaviours at night can prevent the acquisition of self-regulation competencies, which allows the infant to self-soothe back to sleep (144). In addition, maternal night-time parenting was also reported to be associated with maternal postpartum depression symptoms (144). Indeed, qualitative data reported that, following her infant's first non-distressing voicing, a mother with depression symptoms responded to her 12-month old rapidly at night (sometimes < 40 s) (138), which may therefore interfere with self-regulation competencies acquisition (144).

Evidence reports associations between maternal symptoms of postpartum depression or anxiety and their offspring's sleep (120, 138, 149-151). However, only a few prospective studies investigated the direction of these associations and found inconsistent results (120, 137, 149, 150). Regarding CB-PTSD, only two studies examined maternal CB-PTSD symptoms and child sleep (126, 152). Pierrehumbert and colleagues found that maternal CB-PTSD was associated with child sleep at 18 months postpartum, independently of their prematurity status (152), while Garthus-Niegel and colleagues found a prospective relationship of maternal CB-PTSD symptoms at 2 months postpartum on child sleep at two years postpartum (126).

Evidence supports associations between perinatal maternal mental health symptoms (mostly depression), infant sleep, infant temperament (e.g., negative emotionality), and bedtime interactions (144, 153-158). For example, a recent study found that the influence of maternal symptoms of antenatal depression on child night waking was mediated by the maternal perception of infant negative emotionality, also referred to as negative affectivity or negative temperament (153). Alternatively, maternal symptoms of postpartum depression and maternal perception of infant negative emotionality were recently associated with more infant sleep problems perceived by mothers (158). In addition, maternal postpartum depression and anxiety symptoms and maternal interactive bedtime behavior involving active physical comforting predicted infant sleep problems at 12 months postpartum, and the influence of both problematic maternal cognition and infant temperament on the maternal interactive bedtime behavior mediated the relationship between child sleep problems from 12 to 24 months postpartum (156). It is important to note that differences are observed in these studies regarding several factors (e.g., participant age, variables of interest, study designs, and offspring sleep or maternal mental health assessment tools and time points), making it unclear which and how mechanisms are involved in the associations between maternal mental health symptoms and infant sleep.

The complex interplay occurring between parents and infant sleep has been modelised by Sadeh and Anders (143), and then adapted by Sadeh, Tikotzky, and Scher (144) with the transactional model of infant sleep and parenting (Figure 2). This model postulates that infant sleep shares ongoing bidirectional complex relations with a) the distal extrinsic context (e.g., maternal educational level), b) the parenting factors context (e.g., maternal mental health), c) intrinsic infant factors (e.g., infant age), and d) the parent-infant interactive context, including interpersonal systems (e.g., maternal perception of infant temperament) and interactive behaviours factors (e.g., bedtime interactions) (143, 144).

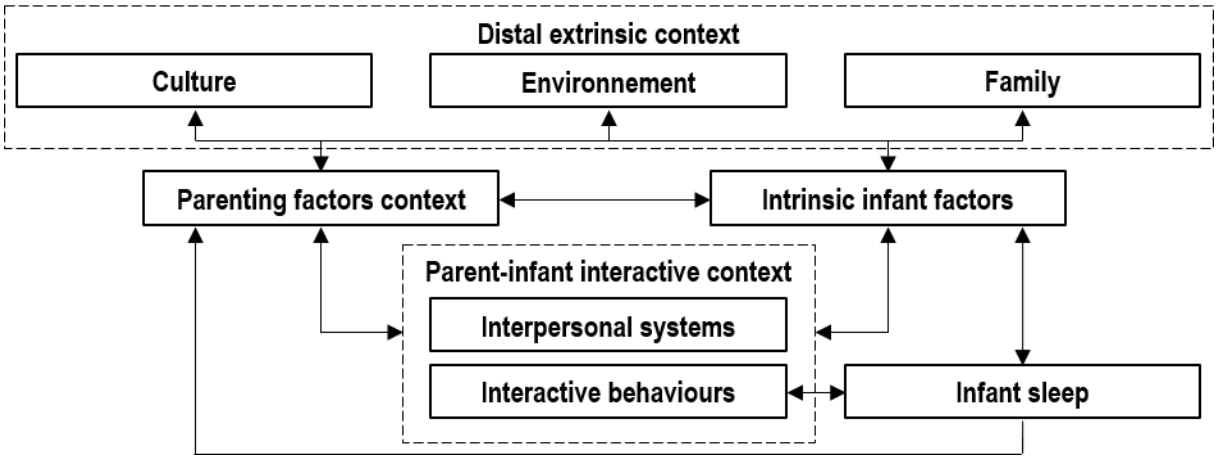


Figure 2. Transactional model of infant sleep and parenting adapted from Sadeh and Anders (143) and Sadeh, Tikotzky, and Scher (144).

As previously mentioned, infant sleep represents a cornerstone of the prevention of adverse developmental outcomes, and research on infant sleep is needed to help prevent adverse clinical outcomes (142). Studies

concluded that maternal mental health symptoms are associated with infant sleep (120, 138, 149-151), but its relation with maternal CB-PTSD symptoms during the first year postpartum has not been examined so far. Further, given that CB-PTSD is comorbid with postpartum depression and anxiety, the question arises of how the interactions of these symptoms contribute to infant sleep. To the best of my knowledge, no research has addressed this point.

1.5. Overarching aim of this thesis

The overarching objective of this thesis was to examine the consequences of traumatic childbirth on the aforementioned aspects of maternal, partner, and infant health within the first year postpartum. The current dissertation was based on the theoretical model of family outcomes after traumatic childbirth shown in Figure 3 (159). According to this model, traumatic childbirth directly impacts psychological vulnerability and physiological stress responses of both mothers and their partner that influence one another. The aftermath of traumatic childbirth on infant outcomes is mediated by parent-infant interactions, which are themselves influenced by maternal and partner outcomes.

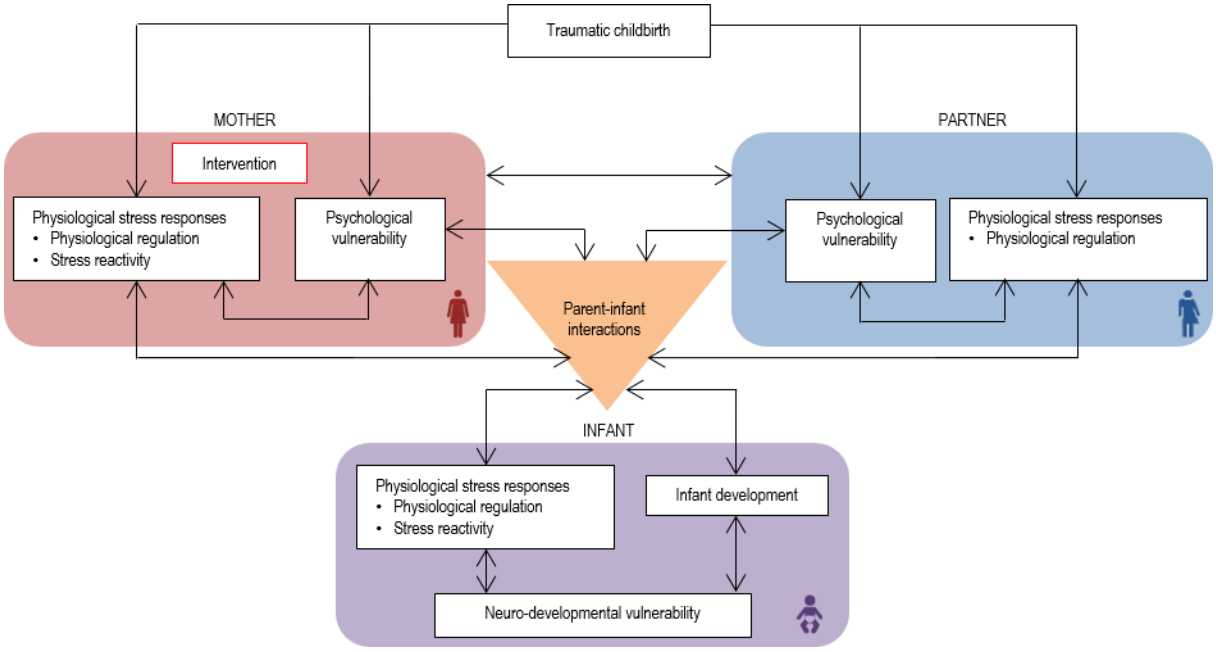


Figure 3. Theoretical model of family outcomes after traumatic childbirth based on Sandoz et al. (159).

The first research question this thesis addressed was how an early brief behavioural intervention including a visuospatial task (i.e., Tetris) delivered to mothers can influence family physiological, psychological, and developmental outcomes, and more specifically maternal CB-PTSD symptoms. To this purpose, the study protocol of the Swiss TrAumatic biRth Trial (START) was developed in the form of a multi-centric double-blind RCT, in the continuity of previous work (15). Data collection of this RCT is still ongoing and the study protocol is described in Study 1.

The second objective of this thesis was to investigate the early postpartum maternal physiological stress reactivity, comparing responses of mothers who had a traumatic childbirth experience with those who did not. The two following sub-questions were answered: 2a. How is the maternal psychophysiological stress reactivity to the LICSP at two to three days postpartum characterised?; and 2b. How does the psychophysiological stress reactivity of mothers at high-risk of CB-PTSD compare to mothers at low-risk of CB-PTSD in response to the LICSP? These questions were addressed in Study 2, via a cross-sectional experimental study.

Lastly, the current thesis aimed to study the distinct influence of maternal symptoms of CB-PTSD, postpartum depression, and anxiety, which are highly comorbid after traumatic childbirth, on infant sleep. More specifically, it focused on the following sub-questions: 3a. Are postpartum depression, anxiety, or CB-PTSD associated with infant sleep?; 3b. Do these different, but comorbid, maternal mental health difficulties share common mechanisms resulting in specific mental health symptom profiles (represented by latent factors)?; and 3c. How do these mental health symptom profiles influence infant sleep, when including maternal perception of infant negative emotionality and method to fall asleep as mediators and maternal educational level and infant age as moderators? Study 3 addressed these gaps in the literature through an online cross-sectional study.

The following chapter contains a summary of these three studies. Although Study 1 and Study 2 are part of START, each research methodology differs and will therefore be presented one after another.

2. Thesis studies

2.1. Study 1: The study protocol of the Swiss TrAumatic biRth Trial

The study protocol of this RCT was published in the journal *BMJ Open* in 2019 and the original published article can be found in Appendix A (159). Note that data collection is ongoing, and that therefore no result is available yet.

2.1.1. Personal contribution

I was significantly involved in designing, establishing, and refining the study protocol, as well as in the writing of the paper. Since the start of my PhD, my main tasks linked to this RCT have consisted of study coordination, co-supervision of research interns, standard operating procedures development, participant recruitment, data collection, ethics committee procedures, and data management.

2.1.2. Aims

This multicentre double-blind RCT aims to examine the effects of an early brief, behavioural intervention (visuospatial task procedure) delivered to mothers on maternal CB-PTSD, but also on parental psychological and physiological outcomes, parent-infant interactions, and infant developmental and physiological outcomes.

2.1.3. Methods

Mothers are included if they: 1. have an ECS at ≥34 weeks gestation at the Lausanne University Hospital or the Geneva University Hospitals; 2. gave birth to a live baby; 3. sign a written consent; and 4. report being traumatised by their ECS (7, 160). The maternal exclusion criteria consist of: 1. established intellectual disability or psychotic illness; 2. insufficient French-speaking level to participate in assessments; 3. severe maternal or infant illness or if the infant requires intensive care; and 4. alcohol abuse or illegal drug use during pregnancy. Maternal participation and permission is mandatory to inform partners of the study. Partner inclusion criteria include: 1. birth attendance; and 2. written consent. Partners are excluded if their French-language skills are insufficient to complete the START assessments. The ethics committee of Vaud approved this study (study number 2017-02142).

As illustrated in Figure 4, participants are randomly allocated to a group, i.e., the intervention or attention-placebo control group, within 6 hours after ECS, at a 1:1 ratio. A computer-generated block randomisation was used to generate the randomisation sequence using blocks of sizes 2, 4 and 6 over 144 participants per stratum (stratified by research centre). To realise the condition-specific cognitive task, participants receive standardised instructions by the clinical team, who does not inform participants about which group they are assigned to. Consequently, the blinding is guaranteed for both the research group and the participants.

The same intervention procedure that was previously described in the literature is used (see section 1.2.1) (15). The cognitive task of the attention-placebo control group consists of a written activity log, in which mothers briefly write down the nature and duration of their ongoing activities (86). To date, there is no preventive treatment to be delivered early after a trauma that could be used as a control condition; the activity log was therefore chosen to control for nonspecific confounding factors, whilst reducing its potential harmful effects (161-164). The attention-

placebo control task was matched with the intervention on important characteristics (86). Both cognitive tasks are performed in a hospital bed for 15 min during the first 6 hours following ECS and are delivered by midwives/nurses. Importantly, the realisation of these cognitive tasks does not interfere with early infant bonding or important routine care procedures.

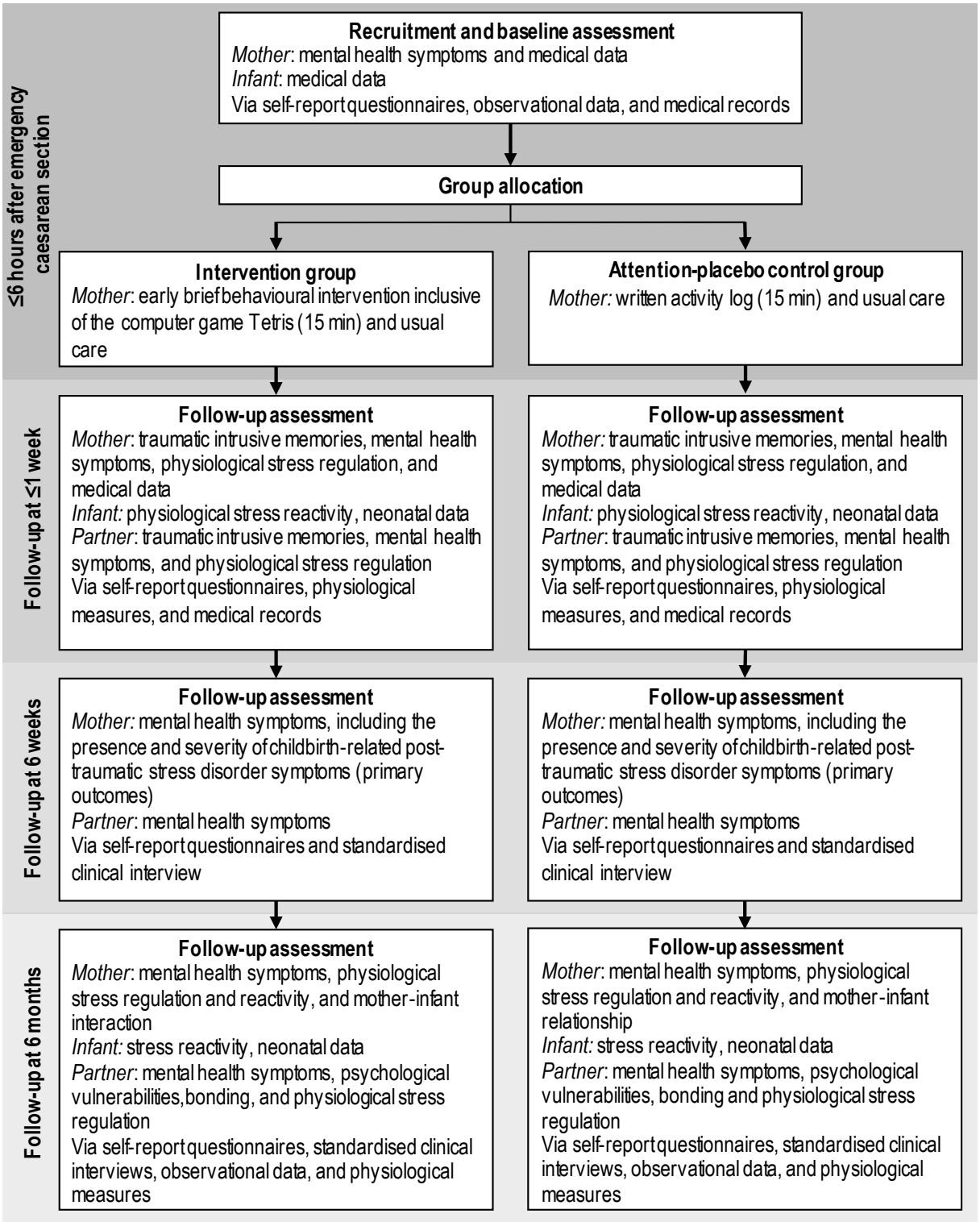


Figure 4. Flowchart of study procedures.

START includes four assessment time points: ≤6 hours after ECS, ≤1 and 6 weeks, and 6 months postpartum (Figure 4). Various maternal, partner, and infant outcomes are assessed. The primary outcomes are the differences in the presence and severity of maternal CB-PTSD symptoms between groups at 6 weeks postpartum. For this purpose, the gold standard clinical interview for PTSD diagnosis (CAPS-5) and a self-report questionnaire (PTSD Checklist for DSM-5) are used (50, 165). Secondary and other outcomes are assessed using self-report questionnaires, standardised clinical interviews, observational data, and physiological measures (Figure 4). Additional information on study outcomes, measures and time points is available in Table 1 and Table 2 of the published article (Appendix A).

Following an *a priori* power analysis based on a previous proof-of-principle RCT (15), a sample size of $n = 120$ participants was required to have 80% power ($\alpha = 0.05$, two-sided) to detect a between-group difference of the primary outcomes of $d = 0.30$. Additional sample size calculations were performed to ensure a sufficient power for secondary outcomes (ranging from $n = 56$ to $n = 84$). We therefore aimed for a recruitment of $n = 144$ mothers to compensate for the estimated 20% drop-out rate.

Group differences regarding the primary outcomes, i.e., the mean subscales and total scores of the PTSD Checklist for DSM-5 and CAPS-5 at 6 weeks postpartum, will be investigated with separate linear regression analyses, controlled for recruitment centre and baseline assessment. Univariate tests will be performed to detect associations between primary outcomes and potential confounders. Regarding the secondary and other outcomes, differences in changes between both groups and the four time point assessments of this RCT will be examined. Analysis will be adjusted for confounding variables that are significantly associated with dependant variables, as described for the primary outcomes. Missing data will be treated with multiple imputation methods, if appropriate.

2.1.4. Conclusion

The findings of Study 1 will address an important gap in the literature regarding the lack of early evidence-based interventions to prevent maternal CB-PTSD (27, 70). The future results of this RCT will allow to attest for the efficacy of an early brief behavioural intervention to reduce maternal CB-PTSD symptoms at 6 weeks postpartum, as previously reported (15). This RCT will also improve our understanding of the effects of such an early intervention on parental psychological and physiological outcomes, parent-infant interactions, and infant development and physiological outcomes.

2.2. Study 2: The Lausanne Infant Crying Stress Paradigm in traumatised *vs.* not traumatised mothers

Study 2 was published in the *Journal of Personalized Medicine* in 2021 (166). The original published article can be found in Appendix B.

2.2.1. Personal contribution

I played a significant role in designing, establishing, refining, and coordinating the study. I also supervised and took part in data collection and cleaning. Moreover, I collaborated with a statistician on the statistical analysis of the data. Finally, I was highly involved in the writing of the published article.

2.2.2. Aims

The first aim of this study was to provide first evidence for the validation of the LICSP as an appropriate stress paradigm eliciting psychophysiological responses in early postpartum mothers (2a; time effect). An increase in salivary cortisol release, of LF power, of LF/HF power, and perceived stress, as well as a decrease of HF power in response to the LICSP were expected. The second objective of this study was to compare psychophysiological stress reactivity of mothers at low- *vs.* high-risk of CB-PTSD (2b; group effect). Given the lack of knowledge on stress reactivity shortly after traumatic stress exposure, no directed hypothesis was formulated.

2.2.3. Methods

The inclusion criteria of this cross-sectional experimental study included: 1. being ≥18 years old; 2. having given birth to a live baby at ≥34 gestational age over the past 5 days; 3. having provided written consent; and 4. being traumatised or not by childbirth to allow group allocation. For this purpose, two screening questions related to the perceived life threat during childbirth for the mother and the infant were asked (7, 159, 160). Participants at low-risk of CB-PTSD had a screening score suggesting they had not perceived a life threat for them or their infant during childbirth, whereas mothers at high-risk of CB-PTSD had a screening score indicating they had experienced a life threat that traumatised them during childbirth. More details on the screening questions and group allocation are available in Appendix C. Exclusion criteria involved: 1. insufficient French language level; 2. established intellectual disability or psychotic illness; 3. antenatal corticosteroids administration; 4. current alcohol abuse and/or illegal drug use; 5. severe maternal and/or infant illness; and 5. infant hospitalised in a neonatal intensive care unit. The high-risk group included 24 participants and the low-risk group 28, forming a total sample size of 52 mothers.

The LICSP procedure is explained in section 1.3.2 and in Figure 1. After the LICSP, participants were asked to complete a brief set of questionnaires during their maternity stay (see the method section of the published article in Appendix B). The study was approved by the ethics committee of Vaud (study number 2017-02142).

Figure 1 illustrates the LICSP measurements and their time points (section 1.3.2). Seven salivary cortisol samples measuring the HPA axis reactivity were taken during the LICSP (C1 to C7). The salivary cortisol peak response was expected between 10 and 30 min post-stress exposure (C3 to C6) (93, 103). Saliva was collected via Sarstedt salivettes and cortisol was extracted from saliva according to standardised procedures. HRV frequency-domain indices such as HF power showing PNS activation, LF power echoing SNS activation, and LF/HF ratio indicating ANS imbalance were calculated using the Kubios HRV Standard software (version 2.3.0) with the Fast Fourier Transformation (110, 112). A VAS ranging from *not at all stressed* (1) to *extremely stressed* (5) assessed perceived stress 10 times during the LICSP (119). Finally, any perceived life threat for the mother and the infant during

childbirth was measured via the two following screening questions: "Did you think that your life was in danger?" and "Did you think that your baby's life was in danger?" (*not at all* = 1 to *extremely* = 7) (7, 159, 160).

An estimation of $n = 40$ was made based on previous studies using the TSST (103, 107, 167). To consider potential lower effect of the LICSP, we aimed to recruit 50 participants completing the entire LICSP procedure. Regarding data analysis, participants having more than 30% missing data were disregarded from the analysis. Otherwise, missing data were imputed using Bayesian linear regression for numerical values, using the mice package v3.11.0 algorithms of R v3.6.1 (running under RStudio v1.1.463) (168, 169). Factorial plan analysis (group x time) using an aligned ranks transformation repeated measures analysis of variances (ART ANOVA; i.e., a non-parametric test) were carried out to test the within effects of each stress reactivity outcome. Post-hoc contrast analysis with Tukey adjustments were conducted to detect differences between relevant pair of assessments to measure stress reactivity to the LICSP. Effect sizes were evaluated using Cohen's *d*. One-way analyses of covariance (ANCOVAs) were conducted to determine group differences on stress reactivity outcomes, using perceived life threat for the infant as a covariate. Finally, given that participants showed elevated cortisol release at C1, C2 was considered as a baseline value for all the statistical analyses.

2.2.4. Results

On average, the birth had occurred 51:04 ± 22:02 hours and minutes before the LICSP. Mothers at high-risk of CB-PTSD reported a higher perceived life threat for the mother ($M = 2.58$, $SD = 2.13$) compared to low-risk mothers ($M = 1.07$, $SD = 0.26$, $W = 211.00$, $p = .002$). Similarly, infant perceived life threat was greater in the high-risk group ($M = 5.08$, $SD = 1.53$) than in the low-risk group ($M = 1.21$, $SD = 0.42$, $W = 6.00$, $p < .001$). All characteristics of the sample are available in Table 1 and Table 2 of the published articles.

Figure 5 depicts maternal stress reactivity over time. Significant time effects were found for all study outcomes, i.e., salivary cortisol ($F(5, 250) = 4.84$, $p < .001$), HF power ($F(3;142.47) = 4.59$, $p = .006$), LF power ($F(3;143.26) = 14.39$, $p < .001$), LF/HF ratio ($F(3;143.47) = 10.42$, $p < .001$), and perceived stress ($F(9, 450) = 43.10$, $p < .001$) (2a). Figure 5 shows relevant significant pairwise comparisons.

Significant or marginal group difference only emerged when controlling for perceived life treat for the infant for salivary cortisol ($F(1, 309) = 5.20$, $p = .023$, $d = 0.53$), HF power ($F(1;197) = 3.32$, $p = .07$, $d = 0.53$), LF/HF ratio ($F(1, 197) = 10.84$, $p < .001$, $d = 0.93$), and perceived stress ($F(1, 517) = 25.89$, $p < .001$, $d = 0.91$) (2b). Hence, high-risk mothers had lower mean of salivary cortisol ($M_{adjusted} = 4.26$, $SD_{adjusted} = 1.96$) and of LF/HF ratio ($M_{adjusted} = 1.59$, $SD_{adjusted} = 2.16$) than low-risk participants (salivary cortisol: $M_{adjusted} = 5.44$, $SD_{adjusted} = 2.40$; LF/HF ratio: $M_{adjusted} = 3.95$, $SD_{adjusted} = 2.83$). Further, the high-risk group showed higher mean of HF power ($M_{adjusted} = 508.01$, $SD_{adjusted} = 351.36$) and of perceived stress ($M_{adjusted} = 2.55$, $SD_{adjusted} = 1.17$) than the low-risk group (HF power: $M_{adjusted} = 287.79$, $SD_{adjusted} = 469.47$; perceived stress: $M_{adjusted} = 1.53$, $SD_{adjusted} = 1.07$).

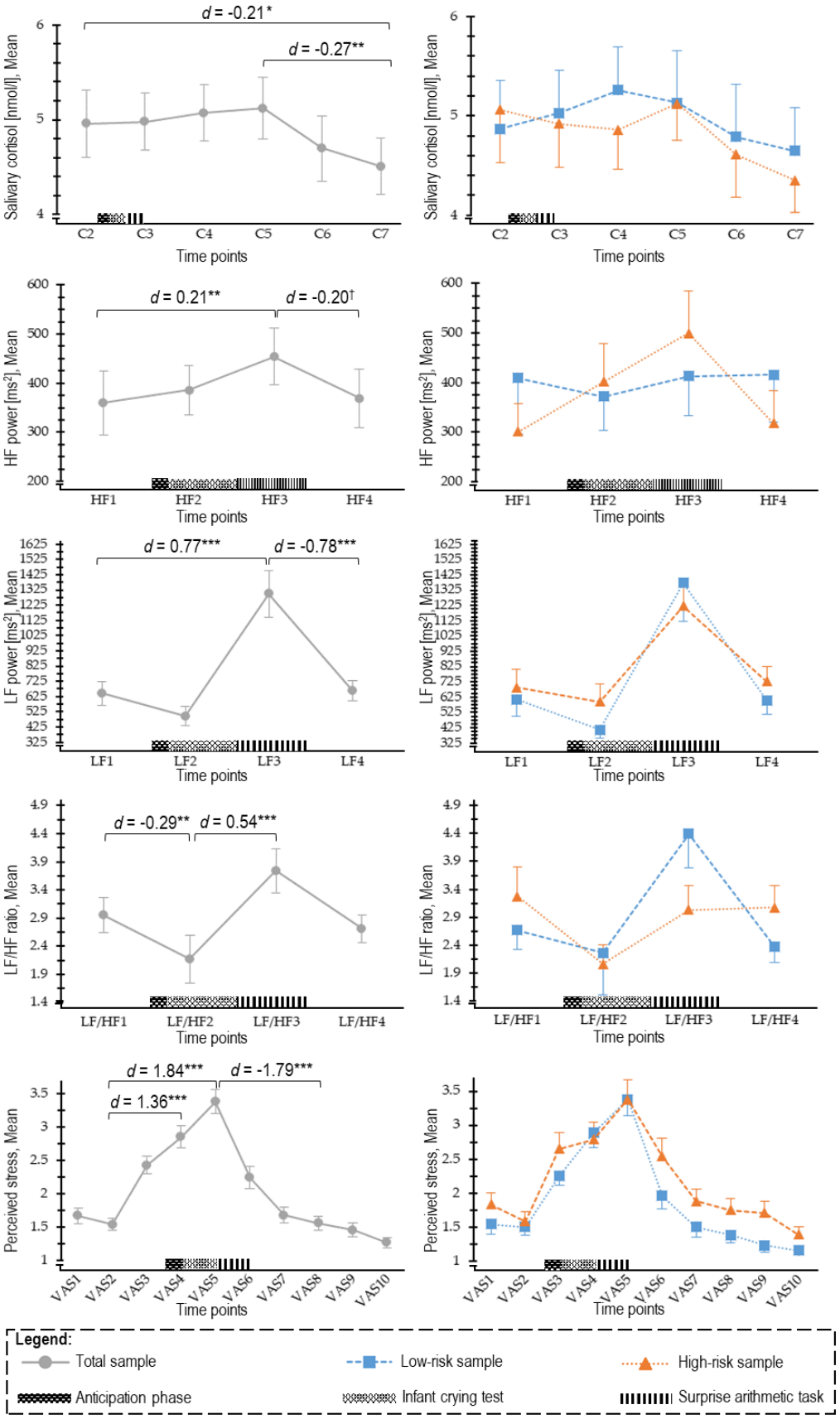


Figure 5. Psychophysiological stress reactivity to the Lausanne Infant Crying Stress Paradigm for the total sample and for each study group. HF = high-frequency; LF = low-frequency; VAS = visual analogue scale ranging from *1* = *not at all* to *5* = *extremely*. Standard error is represented by error bars. †p < .10, *p < .05, **p < .01, ***p < .001.

2.2.1. Conclusion

For the first time, evidence was collected to consider the LICSP as a suited stress paradigm in maternity settings to induce maternal psychophysiological stress reactivity. Mothers at high risk of CB-PTSD showed higher perceived stress and altered ANS and HPA activation in comparison with low-risk participants, when controlling for the infant perceived life threat during childbirth. While replication is needed, these results form the first steps in identifying mothers susceptible to develop CB-PTSD with their early stress responses, leading to important clinical implications for early screening of mothers who need professional support.

2.3. Study 3: The interactive role of maternal mental health on infant sleep

Study 3 was submitted to the journal of *Early Human Development* on the 30th of July 2021 (170). The submitted article in Appendix D.

2.3.1. Personal contribution

I significantly contributed to the design, the establishment, the coordination, and the data management of the study. Together with a statistician, I worked on the statistical analysis. I was highly involved in the article's writing.

2.3.2. Aims

This study firstly aimed to investigate the associations between maternal symptoms of postpartum depression, anxiety, or CB-PTSD and infant sleep (3a). More specifically, we expected to find positive associations between maternal mental health symptoms and infant night waking, and negative associations between maternal mental health symptoms and infant nocturnal sleep duration. Given the high comorbidity between these three maternal mental health difficulties, the second purpose of this study was to exploratory extract data-driven maternal mental health symptom profiles (3b). This led to the third aim, which was to examine the differential influence of these profiles on infant sleep when mediated by maternal perception of infant negative emotionality or the method to fall asleep, and moderated by maternal educational level or infant age. Figure 6 displays the pathways tested.

2.3.1. Method

Participants who took part in an online cross-sectional questionnaire validation study (171) had the option to complete another sub-study measuring infant outcomes (n = 410). Mothers were eligible when they were 1. the birthing parent of a 3-to-12-month old, 2. ≥ 18 years old, and 3. French-speaking. Table 1 of the revised manuscript depicts characteristics of the sample Appendix D. The study was mostly advertised via social media. Data were only saved once the last page of the survey was completed, which meant that information for early dropouts were not recorded. No ethics approval was required for this study (Appendix E).

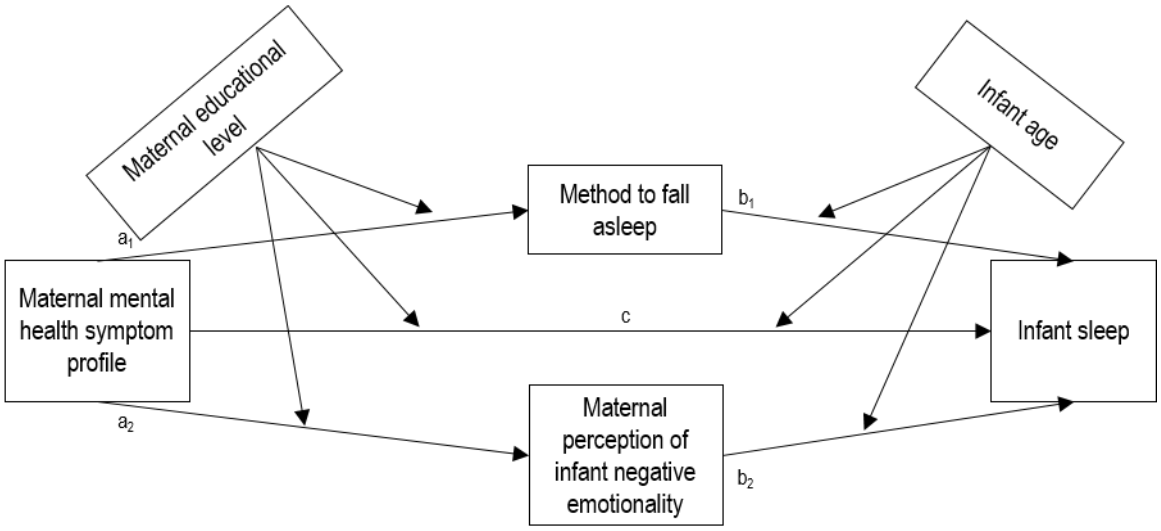


Figure 6. Proposed pathways involved in the associations between maternal mental health symptom profiles and infant sleep, based on Sadeh and Anders (143) and Sadeh, Tikotzky, and Scher (144).

Three self-report questionnaires were also completed by mothers to assess their mental health symptoms. First, the Edinburgh Postnatal Depression Scale (EPDS) collected postpartum depression symptoms within the last week (172). Higher the total score is, higher symptom severity is (range: 0-30) (172). The EPDS had adequate internal consistency (Cronbach α = 0.80) and the French version showed good psychometric characteristics (173). Second, the anxiety subscale of the Hospital Anxiety and Depression Scale (HADS-A) assessed anxiety symptoms over the last week (174). A higher total score (range: 0-21) suggests higher symptom severity (174). The French version had good psychometric characteristics and internal consistency (Cronbach's α = 0.90) (175). Third, the City Birth Trauma Scale (City BiTS) assessed CB-PTSD symptoms during the last month and is composed of two dimensions: the birth-related symptoms and the general symptoms (20). A higher total score (range: 0-60) indicates greater CB-PTSD symptom severity (20). The Cronbach's α in the current study was appropriate at 0.82 and the French version demonstrated good psychometric characteristics (171). Finally, mothers reported some sociodemographic and medical data, such as infant age (*≥3 months to <6 months* = 1, *≥6 months to <9 months* = 2, and *≥9 months to <12 months* = 3) and maternal educational level (*no education* = 1, *compulsory education* = 2, *post-compulsory education* = 3, *university of applied science or university diploma of technology degree* = 4, and *university* = 5).

The Brief Infant Sleep Questionnaire measured, over the last week, nocturnal infant sleep duration (in min), infant night waking, and the method of falling asleep (*while being fed* = 1, *while being rocked* = 2, *while being held* = 3, *alone in the crib* = 4, and *in the crib with parental presence* = 5) (145). This maternal-report questionnaire had good psychometric properties (145). Mothers also filled in the negative emotionality subscale of the Very Short Form of the Infant Behavior Questionnaire-Revised (IBQ-NEG) reflecting the infant tendency to express negative emotions (e.g., sadness, distress to limitation, and fear) (176). A higher IBQ-NEG score indicates higher negative emotionality (range: 1-7) (176). The forward-backward method was used for cultural adaptation and French translation (177). In this study, the IBQ-NEG Cronbach's α was 0.82.

The nocturnal sleep duration variable contained one missing data, which was not imputed, and no outlier was detected. To assess aim 3a, six simple linear regressions were performed, with EPDS, HADS-A, or City BiTS score as the predictor and infant sleep (i.e., nocturnal sleep duration or night waking) as the dependant variable. For aim 3b, an exploratory factor analysis with three predefined factors was conducted to establish maternal mental health symptom profiles. A confirmatory factor analysis was then performed to assess the quality of the model. Finally, for aim 3c, maternal educational level and method of falling asleep were recoded into dichotomous variables. Educational level was comprised of low *vs.* high educational level and the method of falling asleep by being not interactive *vs.* interactive. Twenty-four moderated mediation models were tested using structural equation modelling, each of them including one of the three maternal mental health symptom profiles as the independent variable, one of the two sleep outcomes as the dependant variable, one of the two mediators (i.e., IBQ-NEG or method to fall asleep), one of the two covariates (method to fall asleep or IBQ-NEG), and one of the moderators (i.e., maternal educational level or infant age). Mediation indirect effects were evaluated with bootstrapping methods on 1000 samples.

2.3.2. Results

Table 1 displays results of the simple linear regression models investigating the associations between maternal mental health symptoms (i.e., EPDS, HADS-A, and City BiTS scores) and infant sleep (i.e., night waking and nocturnal sleep duration) (3a).

Table 1. Simple linear regression models for the associations between maternal mental health symptoms and infant sleep

Model	Predictor	Dependent variable	*n*	*β*	R^2	*F*	*p*
1	EPDS	Night waking	410	0.03	0.019	8.08	.005
2	EPDS	Nocturnal sleep duration	409	-2.51	0.039	16.54	< .001
3	HADS-A	Night waking	410	0.04	0.011	4.49	.035
4	HADS-A	Nocturnal sleep duration	409	-2.59	0.016	6.77	.010
5	City BiTS	Night waking	410	0.01	0.004	1.60	.207
6	City BiTS	Nocturnal sleep duration	409	-0.80	0.010	4.17	.042

Note. EPDS = Edinburgh Postnatal Depression Scale; HADS-A = anxiety subscale of the Hospital Anxiety and Depression Scale; City BiTS = City Birth Trauma Scale

The results of the exploratory factor analysis are displayed in Table 3 in Appendix D. The first factor, namely the *depressive profile*, contained 8 EPDS items, 2 HADS-A items, and 8 City BiTS items, with loading values ranging from 0.41 to 0.74. Only 9 items of the City BiTS loaded on the second factor, called the *birth trauma profile*, with loading values from 0.49 to 0.80. Finally, the third factor, which was named the *anxious profile*, consisted of 3 EPDS

items, 4 HADS-A items, and 2 City BiTS items that had loading values between 0.44 to 0.71. The depressive and anxious profiles were highly correlated ($r = 0.81$, $p < .001$), while the birth trauma profile was moderately associated with the depressive profile ($r = 0.41$, $p < .001$) and the anxious profile ($r = 0.46$, $p < .001$). The quality indices resulting from the confirmatory factor analysis indicated an acceptable fit to the data (*RMSEA* = 0.074, *CFI* = =.862, *TLI* = 0.851, *χ2/df* = 3.238, *SRMR* = 0.056) (3b). As shown in Table 2, maternal perception of infant negative emotionality was significantly mediating the association between the depressive profile and the night waking, whatever the infant age (model 1) or the maternal educational level (model 2); the association between the depressive profile and the nocturnal sleep duration but only when the infant age was between 6 and 9 months (model 3); and the association between the anxious profile and the night waking when the infant age was between 3 and 9 months (model 4) or when the education level was high (model 5) (3c). Non-standardised beta coefficients can be found in Figure 1 in Appendix D, while information regarding non-significant moderated mediation models are reported in Appendix F.

2.3.1. Conclusion

Study 3 examined for the first time the distinct influences of different, but comorbid, maternal mental health symptoms on infant sleep. Birth trauma symptoms were not associated with any of the infant sleep outcomes, while the influences of the depressive or anxious profiles on infant sleep were mediated by the maternal perception of infant negative emotionality, but only for some specific infant ages and maternal educational levels. Findings suggest that different mechanisms are involved in the associations between maternal mental health and infant sleep, depending on the type of maternal symptomatology. The impact of traumatic childbirth on infant sleep is not clear during the first year postpartum, and the maternal trauma-related impact on infant sleep may need longer follow-up for associations to unfold, contrary to the depressive or anxious context.

Table 2. Significant moderated mediation models investigating the influence of maternal mental health symptom profiles on infant sleep

Independent variable	Dependent variable	Mediator	Covariate	Moderator	*ACME*, *95% CI*	*p*
Model 1						
Depressive profile	Night waking	IBQ-NEG	Method to fall asleep	Infant age: ≥3 months to <6 months	0.013, [0.006, 0.024]	<.001
Depressive profile	Night waking	IBQ-NEG	Method to fall asleep	Infant age: ≥6 months to <9 months	0.006, [0.001, 0.014]	.02
Depressive profile	Night waking	IBQ-NEG	Method to fall asleep	Infant age: ≥9 months to <12 months	0.009, [0.001, 0.024]	.028
Model 2						
Depressive profile	Night waking	IBQ-NEG	Method to fall asleep	Low educational level	0.007, [0.002, 0.015]	.004
Depressive profile	Night waking	IBQ-NEG	Method to fall asleep	High educational level	0.009, [0.004, 0.017]	<.001
Model 3						
Depressive profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	Infant age: ≥6 months to <9 months	-0.296, [-0.677, -0.067]	.012
Model 4						
Anxious profile	Night waking	IBQ-NEG	Method to fall asleep	Infant age: ≥3 months to <6 months	0.013, [0.004, 0.026]	<.001
Model 5						
Anxious profile	Night waking	IBQ-NEG	Method to fall asleep	High educational level	0.009, [0.001, 0.021]	.032

Note. IBQ-NEG = negative emotionality subscale of the Very Short Form of the Infant Behavior Questionnaire-Revised.

3. General discussion and perspectives

In addition to the economic consequences for society (12, 127), traumatic childbirth has significant negative impacts on maternal, paternal, and infant outcomes (9, 52, 121, 124, 126, 129). Research on maternal and partner physiological and psychological outcomes after traumatic childbirth is lacking, including evidence on the efficacy of early interventions to prevent CB-PTSD (9, 13, 27, 52, 70). Moreover, it is important to stop the ripple effects caused by trauma-related consequences (9, 52). Consequently, this thesis intended overall to fill some literature gaps concerning maternal, partner, and infant health outcomes following traumatic childbirth during the first year postpartum.

The first part of this thesis was the development of a multi-centric double-blind RCT to test the efficacy of an early behavioural intervention on various familial outcomes, including maternal CB-PTSD symptoms (Study 1). Due to COVID-19 consequences, data collection is still ongoing and the current thesis could not incorporate any results. The second part of the thesis focused on maternal psychophysiological stress reactivity during the early postpartum, since altered stress responses could play a major role in CB-PTSD (Study 2) (91, 92). It produced first evidence for the validation of the LICSP as a tool to elicit maternal psychophysiological stress responses at two to three days postpartum. When controlling for the infant perceived life threat during childbirth, mothers at risk of CB-PTSD already showed an altered psychophysiological stress reactivity compared to controls (2b). Finally, the third part of this thesis investigated the associations between maternal mental health symptoms and infant sleep (Study 3). One of the main interests of Study 3 related to the investigation of the distinct influence of three maternal mental health symptom profiles, namely the depressive, birth trauma, and anxious profiles, on infant sleep. Results suggested that the relationship between the depressive or anxious profiles and the adverse infant sleep outcomes was mediated by the maternal perception of infant negative emotionality but only for some specific infant ages and maternal educational levels. In addition, the association between the birth trauma profile and infant sleep was not mediated by this maternal perception of infant temperament.

3.1. Interpretation of findings

Study 1 detailed the study protocol of START, an innovative RCT studying family health outcomes after traumatic childbirth. The primary aim of this ongoing RCT is to assess the preventive effect of an early brief behavioural intervention inclusive of a visuospatial task on the presence and the severity of maternal CB-PTSD symptoms at 6 weeks postpartum. The intervention tested is cost-effective and universal, has no side effects, and can be integrated into routine postpartum care with ease (90). Positive results would be highly valuable, as no early evidence-based treatment for CB-PTSD currently exists (9, 27, 70).

Beyond this primary aim, START investigates the effect of this intervention on many aspects of maternal, partner, and infant health outcomes, such as psychological, physiological, parent-infant relationship, and infant developmental outcomes, as described by the theoretical model of family outcomes after traumatic childbirth (Figure 3). This design, including all the family, is rare in perinatal research, despite the importance of the father during the

perinatal period (13, 52, 65). This RCT run with a high-risk population will provide detailed knowledge on CB-PTSD protective and risk factors, comorbidity, trajectory, and co-interaction of parental symptoms after traumatic childbirth. The findings of this RCT will also determine the mid-term effect of both maternal and partner CB-PTSD symptoms on infant development and their interactive effect in line with the model of intergenerational transmission of stress and trauma (128). START, therefore, represents a significant opportunity to investigate the third pathway of this model, for which research is currently scarce (52).

An important part of this thesis related to maternal psychophysiological stress reactivity in the early postpartum period (Study 2). To the best of my knowledge, this was the first time that variations in maternal early psychophysiological stress reactivity after traumatic childbirth were studied, despite its probable involvement in CB-PTSD development (91, 92). Hence, a key finding of this thesis was the collection of the first evidence for the LICSP validation as an effective paradigm for mild stress induction in maternity settings at two to three days postpartum. More specifically, in response to the cognitive stressor of the LICSP, mothers had an elevation of perceived stress and SNS activation, as expected. A simultaneous increase of PNS activation was also observed, contrary to our hypothesis. However, the HPA axis did not respond to the LICSP stressors, mainly because salivary cortisol levels were already high at baseline and remained elevated until the expected peak response, before declining at the end of the recovery period.

Several reasons as to why the LICSP did not cause an HPA response can be assumed. First, precise LICSP-related requirements and postpartum-specific demands (e.g., maternal and newborn care) may have been stressful for mothers, therefore increasing salivary cortisol release before the start of the stress paradigm. Second, mothers were aware of a short upcoming infant separation during the LICSP. Hence, anticipating this moment may have been more stressful than its actual experience, since salivary cortisol levels were higher when measured during baseline (C1) than during the stress phase (C2). Third, the overall stress level of the stress phase may have been inadequately low to intensify the HPA activation (93). In comparison to the TSST (101, 103), the social-evaluative threat may have been weak during the LICSP, due to the stress phase procedure characteristics (e.g., one experimenter in the LICSP *vs.* a panel of experimenters in the TSST). Moreover, the lack of face-to-face feedback from the experimenter on the maternal performance of the psychosocial stressor could also have reduced the social-evaluative threat (178). Finally, many early postpartum confounders could have impacted HPA activation, such as sleep deprivation, lactation and its associated hormonal release, or parenting challenges (96, 179-183). The fact that our study sample faced many potential early postpartum-specific changes (e.g., breastfeeding initiation) makes it difficult to compare their HPA reactivity to other samples. Moreover, mothers of the current sample showed higher mean cortisol levels than what was previously reported in traumatised *vs.* non-traumatised women (107), which may possibly be associated with general childbirth-induced hormonal changes.

The fact that a simultaneous increase in HF power was observed during the cognitive stressor was unexpected. When looking more carefully at the pattern of HF power mean response, it appears that only traumatised mothers had an increase of HF power. This could be explained by childbirth-related pain resulting in compensatory sympatho-adrenal activation that includes catecholamine release into the circulation system (184). As a result, a

co-activation of SNS and PNS occurs. Although the traumatised group had more ECS and instrumental deliveries, both of which are associated with higher pain intensity at 24 hours postpartum, this does not justify why this increase is not observed in non-traumatised mothers, since pain is frequent during the early postpartum (185).

Another explanation could be related to infant-focused ruminations: an increase of PNS activity was reported under stress in traumatised mothers, potentially caused by ruminations linked to the threat of the separation with their child (186). Thus, the parallel PNS and SNS activation observed in the high-risk group of the current study may be associated with levels of hypervigilance post-trauma, as participants might have had ruminations related to their infant's well-being while performing the ICT (186).

Importantly, this study compared for the first time the early psychophysiological stress responses of mothers with and without traumatic childbirth. Findings showed that the group at risk of CB-PTSD had higher perceived stress and altered ANS and HPA activation compared to non-traumatised mothers, while controlling for the infant perceived life threat. Hence, this suggests that the nature of the perceived life threat, i.e., whether the mother perceived danger for her or her infant, impacts differently the early postpartum psychophysiological stress mechanisms, which could play a major role in CB-PTSD development (91, 92). Given that admission to neonatal intensive care was shown to be a predictor of CB-PTSD (19), this result is not surprising.

The last study of this thesis (Study 3) investigated for the first time the distinct associations between different, but comorbid, maternal mental health difficulties (postpartum depression, anxiety, and CB-PTSD) and infant sleep in the first year postpartum. As expected, significant associations between symptoms of maternal postpartum depression or anxiety and infant sleep were observed, which is in line with previously reported findings (120, 138). In addition, maternal CB-PTSD symptoms were associated with infant nocturnal sleep duration but not with night waking, contrary to our expectations. Hence, CB-PTSD-specific mechanisms associated with infant sleep may be different from the ones linked to postpartum depression or anxiety. Since an alteration of the infant perception was observed in mothers with CB-PTSD symptoms (62), mothers experiencing symptoms of CB-PTSD may have biased beliefs concerning the expected number of their infant's night waking, which might, in turn, affect their reporting. Nonetheless, this remains to be explored in future studies.

The lack of association between CB-PTSD symptoms and night waking may be related to the infant acting as a trauma reminder and thus triggering re-experiencing symptoms in mothers (19, 62). As a consequence, CB-PTSD avoidance symptoms may manifest in mothers in the form of infant-related avoidance, resulting in their partner taking over (19, 62). This is supported by findings showing that mothers with a probable CB-PTSD diagnosis had less desire for closeness to their infant (62). Also, infant-directed hostility and diminished pleasure when interacting with their infant were observed in mothers with CB-PTSD symptoms (62). However, this remains hypothetical, as we did not measure partner involvement.

One of Study 3's important findings was the identification of three types of maternal mental health symptom profiles occurring in the first year postpartum, i.e., the depressive, birth trauma, and anxious profiles. The depressive profile was defined by symptoms of low mood, anhedonia, problems in concentrating, culpability, anger, irritability, social

detachment, and self-destruction. The second profile, which is the birth trauma profile, was composed of birth-related symptoms, such as birth-related intrusive memories, avoidance, and negative mood and cognitions. Lastly, the anxious profile reflected symptoms of abnormal or constant worries, infant-unrelated sleep difficulties, panic, and scare. Hence, the depressive and anxious profiles contained symptoms of postpartum depression, anxiety, and CB-PTSD. On the contrary, the birth trauma profile was only composed of birth-related symptoms of CB-PTSD. As suggested by previous findings (10), this may indicate that postpartum depression, anxiety, and CB-PTSD are not completely distinct childbirth-related phenotypes. Considering the high comorbidity of postpartum depression, anxiety, and CB-PTSD (7, 10, 54, 56), appraising maternal symptomatology via a holistic approach instead of mental health clinical classifications can be relevant for both clinical and research purposes.

Finally, one of the main interests of Study 3 lays in the study of the distinct influences of these maternal mental health symptom profiles on infant sleep. First of all, the association between the depressive profile or the anxious profile and infant sleep was mediated by maternal perception of infant negative emotionality (i.e., a dimension of infant temperament), but only for some specific infant ages and maternal educational levels. Both maternal symptoms of postpartum depression and anxiety have been reported to be associated with maternal perception of infant negative emotionality (187, 188). It was also shown that depressed mothers tended to report more hostile feelings towards their infant and to have a more negative perception of their behaviour in comparison with controls (189). As a consequence of their infant negative perception, depressed or anxious mothers may have adopted a less attuned behaviour towards their infant's needs, impeding the acquisition of self-regulation competencies that are associated with good infant sleepers (190). Therefore, as reflected by the high correlation between the depressive and anxious profiles, the mechanisms involved in the associations between maternal depressive or anxiety symptoms and infant sleep may share similarities.

The association between the depressive profile and infant nocturnal sleep duration was mediated by maternal perception of infant temperament, only when infants were aged 6 to 9 months. From a clinical point of view, paediatricians consider that 6-month olds should sleep at night (191). According to qualitative observations, mothers with elevated depression symptoms and concerns regarding their infant needs at night tended to adopt specific intrusive behaviours that could prime infant nocturnal waking resulting in shorter nocturnal sleep duration (e.g., nursing the infant when they are not hungry, picking them up while they are asleep) (138). The primary aim of these intrusive behaviours of depressive mothers would be to satisfy maternal emotional needs, instead of infant needs (138). In addition, the cessation of breastfeeding potentially occurring around this age (i.e., the prevalence rate of breastfeeding were reported to fall from 60% at 2 months postpartum, to 42% at 6 months postpartum, and 24% at 12 months postpartum (192)) may also be an explanation of this result. Since breastfeeding is often used as a soothing method (191), one can assume that depressed mothers who had a negative perception of their infant temperament may have been in difficulty comforting their infant other than with maximal maternal support (191), which then have impacted nocturnal sleep duration, since infants do not acquire self-regulation competencies (144). Nevertheless, these hypothetical explanations remain to be tested.

The maternal perception of infant negative emotionality also mediated the association between the anxious profile and night waking, only for infants of 3 to 6 months old or when the maternal educational level was high. A high educational level provides information on the socioeconomic environment (193), which, according to the transactional model of infant sleep and parenting, is associated with parental cognitions and style that are related to infant sleep (144). Future research would be needed to investigate in more detail the effect of the socioeconomic environment on the association between maternal anxious symptoms and infant sleep.

Regarding the moderation effect of the infant age, some evidence showed that, in comparison with controls, infants of 4 months old having a mother with a panic disorder woke up more often (194). In addition, these mothers interacted with their infant less sensitively and adopted parenting behaviours that may impede infant sleep (e.g., more night-time feeding) (194). Since the self-regulated sleep period stabilises around 4 months (141), one can assume that, between 3 and 6 months, infants of our sample started to resume sleeping at night without crying. As a consequence, mothers with an anxious profile and a negative infant perception may have adopted, in reaction to this new sleep rhythm, behavioural hypervigilance towards their infant (e.g., checking on the infant if they had not cried for a while to ensure they are healthy). Such intrusive maternal behaviours may therefore have disrupted infant sleep (120). The assumption that intrusive maternal behaviours at night firstly aimed to address maternal anxiety and not infant needs was also postulated by others (138).

Interestingly, the maternal perception of infant temperament did not mediate the association between the birth trauma profile with infant sleep. Therefore, Study 3 suggests that different mechanisms are involved in the associations between maternal mental health and infant sleep, depending on the nature of the experienced maternal symptoms. This result echoes recent findings showing that mother-infant bonding was not associated with birth-related symptoms of CB-PTSD, but was with general symptoms of CB-PTSD and postpartum depression symptoms (131). Therefore, the different dimensions of CB-PTSD (i.e., birth-related symptoms and general symptoms) may have a specific influence on infant outcomes (131). In addition, according to the transactional model of infant sleep and parenting, maternal cognitions linked to infant sleep influence their sleep-related behaviour, which in turn impacts infant sleep (144). Our results, though, could not confirm that the associations between maternal mental health symptom profiles and infant sleep were mediated by an interactive method to fall asleep.

3.2. Clinical implications

Early evidence-based interventions to prevent CB-PTSD are currently lacking (9, 27, 70). Nevertheless, this literature gap may be addressed by START, since its primary aim is to examine the effects of an early brief behavioural intervention inclusive of the computer game Tetris on maternal CB-PTSD (Study 1). Hence, if this RCT can replicate previous findings (15), results would change the current clinical guidelines for mothers after traumatic childbirth. Given that this early brief behavioural intervention does not interrupt routine postpartum care and does not require a mental health professional, its implementation in maternity units should be facilitated, as reported by others in an emergency department (90).

Study 1 should also provide substantial knowledge on the consequences of traumatic childbirth on various aspects of family health outcomes within the 6 months postpartum, as well as on the third pathway of the intergenerational transmission of stress and trauma, which is currently limited (52). Hence, risk factors, but also protective factors, are examined. For example, lack of post-trauma social support was shown to be one of the strongest predictors of PTSD symptom severity in populations that experienced other traumatic events (195, 196). On the contrary, high levels of social ties and social support could promote and buffer both psychological and physical health (197). Although a social model of PTSD has recently been developed, mechanisms involved between social support and (CB-)PTSD require more investigation (198). Another factor worthy of further studies is the quality of the couple relationship. Investigating the protective role of couple relationship could be valuable to shed light on the mechanisms involved in the intergenerational transmission of stress and trauma, since it was shown to influence child development (199). Hence, START could stimulate evidence-based interventions to support early childhood development in the context of parental CB-PTSD.

Findings of Study 2 demonstrated that, in comparison with controls, traumatised mothers showed different psychophysiological stress mechanisms at two to three days postpartum already, when controlling for infant perceived life threat. Although more research is needed, these results provide preliminary evidence that some physiological indicators could be used to identify mothers at risk of CB-PTSD rapidly after childbirth. According to the model of intergenerational transmission of stress and trauma, maternal biological changes resulting from traumatic stress exposure may interfere with early postnatal care and thus impede appropriate mother-infant interactions (128). Early detection of mothers at risk of CB-PTSD is therefore primordial to prevent intergenerational transmission of stress and trauma-related consequences.

Although Study 3 reported that maternal postpartum depression, anxiety, and CB-PTSD symptoms were predictors of adverse infant sleep outcomes, the clinical effects were small. For example, for every one unit increase in the EPDS total score (reflecting maternal postpartum depression symptoms), there was a decrease of 2.51 min of nocturnal sleep. Parents should helpfully be told that night waking is observed in most infants and children (144, 157). In comparison with fathers, mothers tend to set fewer limits, which in turn restricts the infant's ability to learn self-soothing with minimal parental support (190). Currently, mechanisms involved in the associations between depressive or anxious profiles and infant sleep are not clear. For example, the direction of the associations between maternal mental health symptoms and infant sleep are unknown due to the cross-sectional design of this study (144). However, our findings suggest that tackling negative maternal perception of their infant temperament could be a key therapeutic element. Hence, future infant sleep interventions should focus on reviewing and modifying maternal perception of infant negative emotionality.

3.3. Theoretical implications of the thesis and research perspectives

The findings of this thesis contribute to a better understanding of the family outcomes after traumatic childbirth. Figure 7 displays the adapted theoretical model of family outcomes after traumatic childbirth, according to the scientific contributions made by the current work. This thesis investigated the nature of the perceived life threat

during childbirth, maternal physiological stress reactivity, maternal psychological vulnerability, infant sleep, and maternal-infant interactive context (previously called maternal-infant interactions).

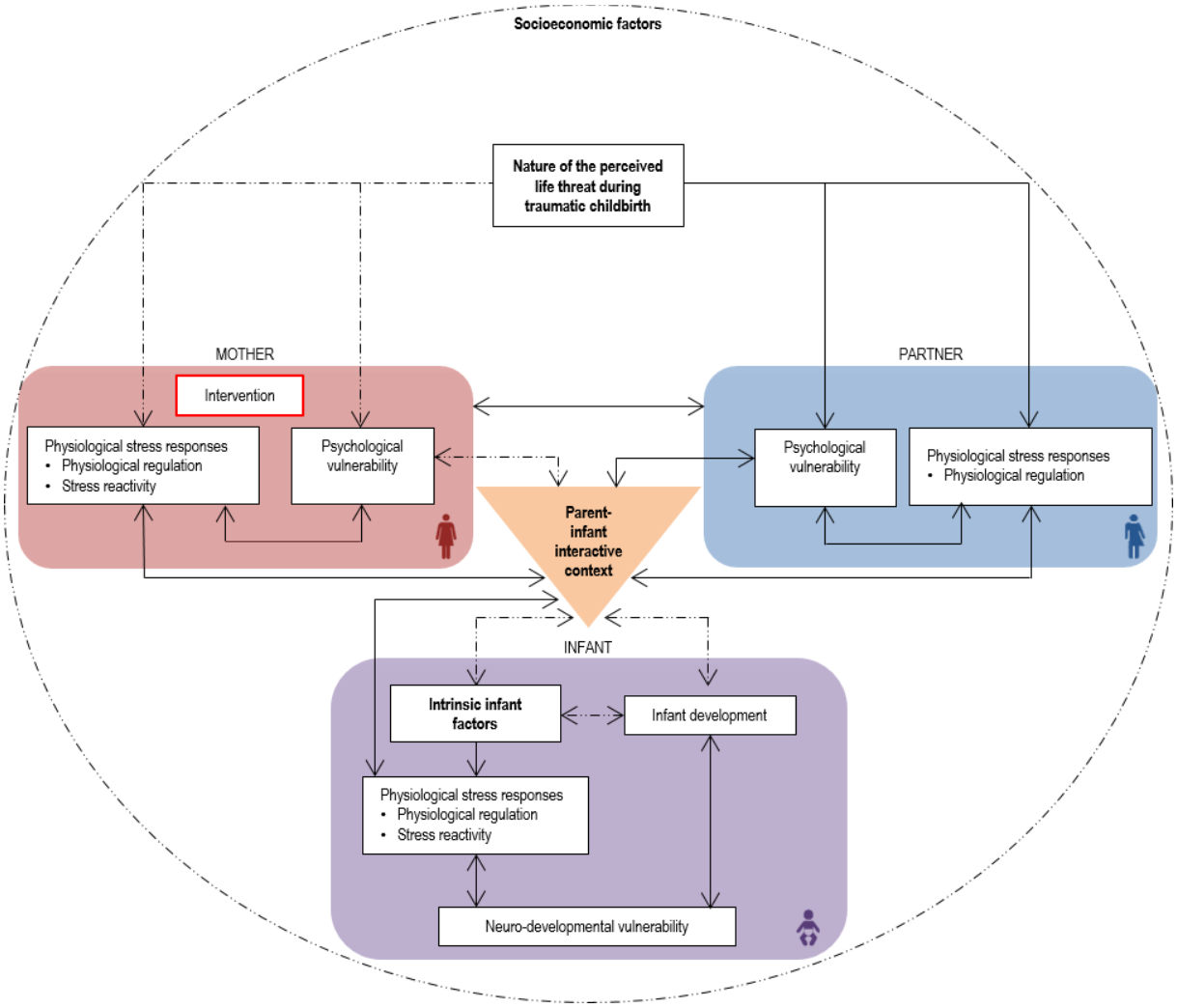


Figure 7. Adapted theoretical model of family outcomes after traumatic childbirth based on Sandoz et al. (159). All the relations are investigated in Study 1, but only dashed lines represent the ones studied in Study 2 and Study 3. Bold variables displayed in the model were added following the findings of this thesis.

This thesis also hypothesised that the association between maternal psychological vulnerabilities and infant sleep (represented in the model with infant development) was mediated by the parent-infant interactive context between. Study 3 concluded that maternal depression, anxiety, and CB-PTSD symptoms were predictors of less infant nocturnal sleep duration. While associations between postpartum depression, anxiety, and infant sleep were already reported in literature (150), this was the first time that an association between symptoms of CB-PTSD and a dimension of infant sleep was demonstrated within the first year postpartum. However, contrary to postpartum depression and anxiety symptoms, we could not confirm that CB-PTSD symptoms predicted infant night waking. Given that the maternal perception of infant negative emotionality mediated the associations between adverse sleep outcomes and maternal depressive or anxious profiles, we could partially confirm the hypothesis that the

psychological vulnerability to infant sleep link was mediated by the parent-infant interactive context. In addition, findings of this thesis suggest a moderating role of intrinsic infant factors (e.g., infant age) and socioeconomic factors (e.g., maternal educational level). Therefore, these two components were added to the theoretical model.

As previously mentioned, the results of this thesis reinforced some associations postulated by the theoretical model of family outcomes after traumatic childbirth. However, they also raised other scientific questions or remaining gaps in the literature that warrant further investigations. First of all, assuming START results will be conclusive (Study 1), the next step would be to conduct an implementation study. Indeed, given that it requires 17 years for evidence to be implemented into clinical care, and that only 14% of evidence is implemented, it is primordial to make sure that families can take advantage of this intervention rapidly (200, 201). In addition, research would be needed to formally evaluate the costs of such an early brief evidenced-based intervention inclusive of a visuospatial task and its subsequent savings (90). Furthermore, there is valid reason to assume that this early brief behavioural intervention inclusive of a visuospatial task could be efficient in partners, since they are also at risk of developing CB-PTSD after traumatic childbirth (13, 14, 16, 29, 39-49). Additional research is, therefore, necessary to investigate the impact of this intervention on partner CB-PTSD symptoms.

Future research would also be required to evaluate if the 6 hours consolidation window can be extended. Indeed, one of the frequent reasons for mothers to decline participation in START is because they are exhausted and prefer to rest. There is, therefore, a clinical argument for this research question. From a theoretical point of view, memory consolidation is a continuous processing, which progressively fades over time (79). Hence, receiving the intervention slightly later than 6 hours postpartum may still take place during the memory consolidation window, and therefore, be efficient. Further, given that mothers are still hospitalised and receiving care during the acute postpartum period, the hospital context may provide an ongoing *in vivo* cue, keeping the traumatic memory malleable (15, 202, 203).

Regarding the LICSP, perinatal stress research has now a validated and standardised stress paradigm to investigate the physiological stress mechanisms potentially involved in the development of maternal CB-PTSD, opening, therefore, many avenues of research. Certainly, the procedure would first benefit from further adaptations, including a revision of the baseline conditions to allow an appropriate measure of HPA activation and an adjustment of the psychosocial stressor of the stress phase to induce more acute physiological stress reactivity.

According to our results, the infant perceived life threat during childbirth seems to play a specific role in the early physiological stress mechanisms, potentially involved in CB-PTSD development. Therefore, future research should examine whether the maternal perceived life threat for herself and/or the infant has a differential or cumulative influence on the CB-PTSD development. The perceived life threat for a loved one, such as one's infant, is a characteristic of traumatic childbirth, as also shown by associations of infant hospitalization or low 1-min Apgar score with parental CB-PTSD (19, 42). Therefore, one could assume that early physiological stress mechanisms potentially involved in CB-PTSD may differ from the ones implicated in PTSD, since other types of traumatic events usually involved a perceived life threat for oneself (e.g., sexual assault). If this hypothesis is confirmed with future research, this would support the proposition that CB-PTSD represents a subtype of PTSD (18).

In addition, to assess the predictability of the LICSP on CB-PTSD, longitudinal studies must be conducted to help to identify risk factors, to clarify mechanisms underlying the development of CB-PTSD, and to highlight mental health biomarkers (104). Moreover, research examining the evolution of both physiological stress responses of traumatised mothers and their infant at birth and later on could shed light on the mechanisms underlying the intergenerational transmission of stress and trauma.

Regarding infant sleep, aetiology of its association with maternal mental health is not clear, despite the large body of evidence showing a link between maternal depression or anxiety symptoms and infant sleep (120, 138, 142, 149-151). The transactional model of infant sleep and parenting reports evidence for bidirectional associations (143, 144). However, due to various methodology and inconsistent results in literature, the causal associations or the direction of prediction between maternal mental health and their offspring's sleep still need to be clarified (126, 138, 144, 204-206). One could hypothesize that, first, these associations are parent-driven, and when infant sleep problems become chronic and prolonged, they are infant-driven, resulting in bidirectional associations (137, 138, 207).

Additionally, according to the adapted theoretical model of family outcomes after traumatic childbirth, future research should investigate the mechanisms underlying the associations between maternal mental health symptom profiles, infant sleep, maternal perception of infant negative emotionality, socioeconomic factors, and intrinsic infant factors. Given that maternal CB-PTSD symptoms at 2 months postpartum were recently prospectively associated with child sleep at two years postpartum (126), this indicates that the consequences of the intergenerational transmission of stress and trauma on infant sleep may only appear after the first year postpartum. Future research examining infant sleep should also integrate physiological and psychological measures in both parents during pregnancy and postpartum, and use objective measures for sleep, such as an actigraphy (144).

Finally, a crucial aspect of this thesis relates to the maternal subjective perception of their infant, whether it is infant perceived life threat during childbirth, or their temperament, supporting the importance of considering mothers as a component of a whole family. Mothers are not only women, they also are both caregivers interacting with a growing infant and co-parents usually involved in a romantic relationship. In line with this, an editorial recently argued for the extension of the focus of perinatal mental health in mothers to the family context (51). Authors examined the role and implications of the perinatal context for parental mental health, couple relationship, child parenting, and parent-child relationship through a Research Topic of 29 articles (51). Besides encouraging future research on protective factors and positive outcomes with various types of population (e.g., families in low- and middle-income countries or LGBTQIA+ families) and partner-sensitive measures, the importance of conducting studies with dyadic and triadic designs was also strongly highlighted (51). Therefore, it is primordial for future research to consider the family as a whole and to develop study design accordingly, as this was done in Study 1.

3.4. Strengths and limitations of this thesis

This thesis demonstrates several strengths. First of all, it is innovative. Study 1 tackles an important literature gap (27, 70). Hence, START will provide crucial knowledge on an early evidence-based intervention to prevent CB-

PTSD. In addition, it considers the family as a whole, which is the exception rather than the rule in literature (51, 52). START findings will allow a global understanding of the mechanisms involved in the intergenerational transmission of stress- and trauma-related consequences. Moreover, the validation of a new maternal stress paradigm for the early postpartum period also represents an important innovation for perinatal stress research, as exposed in Study 2. For the first time, maternal stress reactivity in the first days following childbirth was studied and altered psychophysiological stress reactivity in mothers at risk of CB-PTSD, when controlling for the infant perceived life threat, could be observed. Finally, Study 3 adopted an innovative approach to examine the associations between maternal mental health difficulties and infant sleep by studying mental health symptom profiles instead of mental health clinical classifications.

The second strength of the current work lies in the methodological rigour adopted throughout the studies. Study 1 reported the main recommended information when publishing a study protocol for a clinical trial (208), whereas Study 2 and Study 3 followed the STROBE reporting statements (209). Further, all studies used validated self-report questionnaires. Study 1 was based on a multi-method assessment: self-report questionnaires, clinical interviews, clinical observations, and physiological measures. Concerning Study 2, validated physiological stress measurements, such as salivary cortisol or HRV parameters, were used. Finally, Study 1 assessed important cofounders whose influence on CB-PTSD development and the intergenerational transmission of stress and trauma were highlighted in literature (e.g., postpartum and antenatal depression symptoms, acute stress disorder symptoms, or history of traumatic event) (14, 32, 52). Furthermore, both Study 2 and Study 3 take into account important variables that could influence their findings (e.g., infant perceived life threat, maternal educational level, and infant age). The validity of the results is, therefore, enhanced.

The third strength relates to the fact that the current work is theory-driven (210). Thus, given that the theoretical framework, which this thesis relies on, is derived from empirically validated theories, drawn conclusions are very likely to be meaningful and generalizable (210). As a result, it allows a relevant and scholarly contribution to knowledge on the consequences of traumatic childbirth on the whole family (210, 211).

Fourth, this thesis used appropriate statistical analysis techniques in close collaboration with a statistician. Study 2 used ART ANOVA, which is a nonparametric factorial analysis, instead of performing a two-way repeated measure ANOVA with violated assumptions that inflates Type I error rates (212). Advanced analyses including moderators and mediators were performed in Study 3. As a consequence, the potential insights that could be gained from each study were maximised.

Finally, this thesis addresses a timely topic and has important clinical and research implications. For several years now, interest in traumatic childbirth and its consequences has increased, as demonstrated by the growing number of works published on this topic during the last few years. Indeed, PubMed research including the MESH terms "Stress Disorders, Traumatic" and "Parturition" showed that from 2003 to 2013, only 7 articles were published on average per year, whereas from 2014 to 2020, there was a mean of 24 published papers each year (213). In addition, as previously mentioned, this thesis opens the path to relevant clinical and research perspectives, which are described in section 3.2 and section 3.3.

Nonetheless, some limitations must be pointed out. The first limitation of this thesis concerns study populations. Due to ethical considerations, the eligibility criteria of Study 1 and Study 2 make the samples less representative of the complete high-risk population. For example, mothers with an infant hospitalised in neonatal intensive care were excluded despite it being a risk factor for CB-PTSD development (19). Since advertisement for Study 3 was mainly made on social media, a self-selection bias cannot be excluded. Hence, mothers with an interest in their mental health and/or infant development might have been more likely to engage in the survey, potentially decreasing the external validity of the results.

A second limitation of this thesis relates to the timeframe. In Study 1, both parental and infant outcomes are only assessed up to 6 months postpartum, although this is due to the funding structure. While Study 3 includes measurements up to 1 year postpartum, a full understanding of the parental trauma-related impact on child development may need a longer follow-up for associations to unfold (124, 126).

Thirdly, the absence of longitudinal designs in Study 2 and Study 3 is an important limitation. A cross-sectional design prevented us from investigating the predictive role of psychophysiological stress reactivity in maternal CB-PTSD development in Study 2, and no prospective association could be studied in Study 3 (144).

Finally, Study 2 and Study 3 did not examine the protective role that some factors could play on stress reactivity or infant sleep. For example, examining the role of social support or the quality of the couple relationship on stress reactivity or infant sleep could have been interesting. Indeed, social support was reported to moderate the effect of TSST (167), potentially indicating that early evidence-based prevention could integrate a social support component. Besides, couple relationship was shown to influence child development, suggesting once more that perinatal research must include all family members (199).

4. General conclusion

This thesis aimed to fill some literature gaps concerning maternal, partner, and infant outcomes following traumatic childbirth based on the theoretical model of family outcomes after traumatic childbirth (159). Firstly, it addressed the lack of early evidence-based interventions to prevent maternal CB-PTSD (27, 70) with START (Study 1). In addition, START also examines the effects of this intervention on partner health outcomes and the intergenerational transmission of stress and trauma. Given this RCT is still ongoing, results could not be discussed. If START is conclusive, findings will improve our understanding of such an early intervention on maternal CB-PTSD symptoms, but also on other family outcomes.

Secondly, this thesis validated a new standardised stress paradigm, namely the LICSP, for the early postpartum period, allowing for the first time to examine early maternal physiological stress reactivity (Study 2). This cross-sectional experimental study showed that traumatised mothers had altered ANS and HPA reactivity, when controlling for the infant perceived life threat, already at two to three days postpartum. While replication and revision of the LICSP are needed, these results are promising for the future development of an early screening of mothers at risk of CB-PTSD.

Finally, this thesis examined associations between postpartum maternal mental health and infant sleep, with the main focus on the distinct effects of different, but comorbid, maternal mental health symptom profiles on infant sleep, while taking into account theory-driven mediators and moderators (Study 3). When including mediators and moderators, no significant association was observed between birth trauma symptoms and infant sleep, suggesting that the consequences of the intergenerational transmission of stress and trauma may unfold later on. Inversely, this online cross-sectional study could confirm the mediation effect of the maternal perception of infant negative emotionality on the influence of maternal depressive and anxious symptom profiles on adverse infant sleep outcomes. The maternal educational level or infant age moderated these associations. The findings suggest that maternal perception of infant temperament is a key therapeutic element and must not be neglected in mothers with mental health symptoms.

In sum, the scholarly contributions of this thesis pave the way for new research questions. Future studies should focus on the investigations of early physiological stress responses to develop a screening intervention identifying mothers at risk of CB-PTSD, the role of the nature of the perceived life threat in CB-PTSD development, the direction of the associations between maternal mental health symptom profiles and infant sleep outcomes, as well as the influence of intrinsic infant, socioeconomic factors. To conclude, given that mothers, partners, and their infant are interconnected components of a system, it is equally primordial for future research to adopt triadic study designs to investigate the aftermath of traumatic childbirth.

5. Output and contribution to science

The Lausanne Perinatal Research Group, which I am part of, is a multidisciplinary research group composed of psychologists, midwives, nurses, and graduate students, which collaborate closely with perinatal clinicians, such as obstetricians, neonatologists, paediatricians, or child psychiatrists. Although the main part of my PhD was linked to the START coordination, I was pleased to have the opportunity to be involved in other research projects led by both research colleagues and clinical collaborators during the last few years, as shown in my publication list (section 7). In addition, I increased my clinical skills through frequent contact with participants: I trained for the Neonatal Behavioral Assessment Scale (214), the Bayley Scales of Infant Development (215), the CAPS-5 (50), and the Structured Play Interaction Scales (216-218). Co-coordinating a RCT allowed me to co-supervise a team of psychological and nursing students and psychologists (Appendix G), to develop a scientific rigour, to gain experience in good research practice, to work for and in a multidisciplinary team, to be resilient to unexpected events, and therefore, to be creative to find solutions. During my PhD I successfully co-supervised three master theses, which taught me how to constructively and efficiently provide feedback (Appendix G). In addition, I took various public and scientific engagements (Appendix G). For example, I was actively involved in the Early Career Researchers section of the Society for Reproductive and Infant Psychology or in the establishment of the Interdisciplinary Academy for Early Childhood Researchers of the Swiss Society for Early Childhood Research. Moreover, I had the opportunity to present my work at various national and international conferences (Appendix G), which helped me to be more confident in my research and to speak with more ease in front of an audience. I also talked about the mental health of partners in the perinatal period on the YouTube channel of *Le Fou de Normandie*. Last but not least, I participated in *Ma thèse en 180 secondes*, and I won the public prize, showing once more the increasing interest in traumatic childbirth and its consequences on the family.

6. References

1. Rosich-Medina A, Shetty A. Paternal experiences of pregnancy and labour. British Journal of Midwifery. 2007;15(2):66-74.
2. Soet JE, Brack GA, Dilorio C. Prevalence and predictors of women's experience of psychological trauma during childbirth. Birth. 2003;30(1):36-46.
3. Beck CT. Middle Range Theory of Traumatic Childbirth: The Ever-Widening Ripple Effect. Global Qualitative Nursing Research. 2015;2:1-13.
4. Johnson MP. The implications of unfulfilled expectations and perceived pressure to attend the birth on men's stress levels following birth attendance: a longitudinal study. Journal of Psychosomatic Obstetrics & Gynecology. 2002;23(3):173-82.
5. Ayers S. Delivery as a traumatic event: prevalence, risk factors, and treatment for postnatal posttraumatic stress disorder. Clinical obstetrics and Gynecology. 2004;47(3):552-67.
6. Creedy DK, Shochet IM, Horsfall J. Childbirth and the development of acute trauma symptoms: incidence and contributing factors. Birth. 2000;27(2):104-11.
7. American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 5 ed. Arlington, VA: American Psychiatric Publishing; 2013.
8. King L, McKenzie-McHarg K, Horsch A. Testing a cognitive model to predict posttraumatic stress disorder following childbirth. BMC pregnancy and childbirth. 2017;17(1):32.
9. Horsch A, Garthus-Niegel S. Posttraumatic stress disorder following childbirth. In: Herring CPJ, editor. Childbirth, Vulnerability and Law: Exploring Issues of Violence and Control. 1st ed. London: Routledge; 2019. p. 49-66.
10. Dekel S, Ein-Dor T, Dishy GA, Mayopoulos PA. Beyond postpartum depression: posttraumatic stress-depressive response following childbirth. Archives of Women's Mental Health. 2020;23(4):557-64.
11. Andersen LB, Melvaer LB, Videbech P, Lamont RF, Joergensen JS. Risk factors for developing posttraumatic stress disorder following childbirth: a systematic review. Acta obstetricia et gynecologica Scandinavica. 2012;91(11):1261-72.
12. Berger A, Bachmann N, Signorell A, Erdin R, Oelhafen S, Reich O, et al. Perinatal mental disorders in Switzerland: prevalence estimates and use of mental-health services. Swiss Medical Weekly. 2017;147(0910):w14417.
13. Bradley R, Slade P. A review of mental health problems in fathers following the birth of a child. Journal of reproductive and infant psychology. 2011;29(1):19-42.
14. Schobinger E, Stuijfzand S, Horsch A. Acute and post-traumatic stress disorder symptoms in mothers and fathers following childbirth: a prospective cohort study. Frontiers in Psychiatry 2020;11(1502).
15. Horsch A, Vial Y, Favrod C, Morisod Harari M, Blackwell SE, Watson P, et al. Reducing intrusive traumatic memories after emergency caesarean section: a proof-of-principle randomized controlled study. Behaviour research and therapy. 2017;94:36-47.

16. Kress V, von Soest T, Kopp M, Wimberger P, Garthus-Niegel S. Differential predictors of birth-related posttraumatic stress disorder symptoms in mothers and fathers – a longitudinal cohort study. Journal of affective disorders. 2021;292:121-30.
17. Olde E, van der Hart O, Kleber R, van Son M. Posttraumatic stress following childbirth: a review. Clinical psychology review. 2006;26(1):1-16.
18. Horesh D, Garthus-Niegel S, Horsch A. Childbirth-related PTSD: is it a unique post-traumatic disorder? Journal of Reproductive and Infant Psychology. 2021;39(3):221-4.
19. Harrison SE, Ayers S, Quigley MA, Stein A, Alderdice F. Prevalence and factors associated with postpartum posttraumatic stress in a population-based maternity survey in England. Journal of affective disorders. 2020;279:749-56.
20. Ayers S, Wright DB, Thornton A. Development of a measure of postpartum PTSD: the City Birth Trauma Scale. Frontiers in psychiatry. 2018;9:409.
21. Nakić Radoš S, Matijaš M, Kuhar L, Anđelinović M, Ayers S. Measuring and conceptualizing PTSD following childbirth: validation of the City Birth Trauma Scale. Psychological Trauma: Theory, Research, Practice, and Policy. 2020;12(2):147-55.
22. Webb R, Smith AM, Ayers S, Wright DB, Thornton A. Development and validation of a measure of birth-related PTSD for fathers and birth partners: the City Birth Trauma Scale (partner version). Frontiers in Physiology. 2021;12(545).
23. Bayrı Bingöl F, Bal MD, Dişsiz M, Sormageç MT, Yildiz PD. Validity and reliability of the Turkish version of the City Birth Trauma Scale (CityBiTS). Journal of Obstetrics and Gynaecology. 2020:1-9.
24. Caparros-Gonzalez RA, Romero-Gonzalez B, Peralta-Ramirez MI, Ayers S, Galán-Paredes A, Caracuel-Romero A. Assessment of posttraumatic stress disorder among women after childbirth using the City Birth Trauma Scale in Spain. Psychological Trauma: Theory, Research, Practice, and Policy. 2021.
25. Handelzalts JE, Hairston IS, Matatyahu A. Construct validity and psychometric properties of the Hebrew version of the City Birth Trauma Scale. Frontiers in Psychology. 2018;9:1726.
26. Horsch A, Ayers S. Childbirth and stress. In: Fink G, editor. Stress: Concepts, Cognition, Emotion, and Behavior. San Diego, CA: Academic Press; 2016. p. 325-30.
27. McKenzie-McHarg K, Ayers S, Ford E, Horsch A, Jomeen J, Sawyer A, et al. Post-traumatic stress disorder following childbirth: an update of current issues and recommendations for future research. Journal of Reproductive and Infant Psychology. 2015;33(3):219-37.
28. Bradley R, Slade P, Leviston A. Low rates of PTSD in men attending childbirth: a preliminary study. British Journal of Clinical Psychology. 2008;47(3):295-302.
29. Helle N, Barkmann C, Ehrhardt S, Bindt C. Postpartum posttraumatic and acute stress in mothers and fathers of infants with very low birth weight: cross-sectional results from a controlled multicenter cohort study. Journal of affective disorders. 2018;235:467-73.
30. Grekin R, O'Hara MW. Prevalence and risk factors of postpartum posttraumatic stress disorder: a meta-analysis. Clinical psychology review. 2014;34(5):389-401.

31. Dikmen-Yildiz P, Ayers S, Phillips L. The prevalence of posttraumatic stress disorder in pregnancy and after birth: a systematic review and meta-analysis. Journal of affective disorders. 2017;208:634-47.
32. Ayers S, Bond R, Bertullies S, Wijma K. The aetiology of post-traumatic stress following childbirth: a meta-analysis and theoretical framework. Psychological Medicine. 2016;46(6):1121-34.
33. Söderquist J, Wijma B, Wijma K. The longitudinal course of post-traumatic stress after childbirth. Journal of Psychosomatic Obstetrics & Gynecology. 2006;27(2):113-9.
34. Ayers S, Pickering AD. Do Women Get Posttraumatic Stress Disorder as a Result of Childbirth? A Prospective Study of Incidence. Birth. 2001;28(2):111-8.
35. White T, Matthey S, Boyd K, Barnett B. Postnatal depression and posttraumatic stress after childbirth: prevalence, course and co-occurrence. Journal of Reproductive and Infant Psychology. 2006;24(2):107-20.
36. Dikmen-Yildiz P, Ayers S, Phillips L. Longitudinal trajectories of post-traumatic stress disorder (PTSD) after birth and associated risk factors. Journal of affective disorders. 2018;229:377-85.
37. World Health Organization. Fatherhood and Health outcomes in Europe. 2007.
38. Lindberg I, Engström Å. A qualitative study of new fathers' experiences of care in relation to complicated childbirth. Sexual & Reproductive Healthcare. 2013;4(4):147-52.
39. Zerach G, Magal O. Anxiety Sensitivity Among First-Time Fathers Moderates the Relationship Between Exposure to Stress During Birth and Posttraumatic Stress Symptoms. The Journal of Nervous and Mental Disease. 2016;204(5):381-7.
40. Leach LS, Poyser C, Cooklin AR, Giallo R. Prevalence and course of anxiety disorders (and symptom levels) in men across the perinatal period: a systematic review. Journal of affective disorders. 2016;190:675-86.
41. Shaw RJ, Bernard RS, DeBlois T, Ikuta LM, Ginzburg K, Koopman C. The Relationship Between Acute Stress Disorder and Posttraumatic Stress Disorder in the Neonatal Intensive Care Unit. Psychosomatics. 2009;50(2):131-7.
42. Aftyka A, Rybojad B, Rosa W, Wróbel A, Karakuła-Juchnowicz H. Risk factors for the development of post-traumatic stress disorder and coping strategies in mothers and fathers following infant hospitalisation in the neonatal intensive care unit. Journal of Clinical Nursing. 2017;26(23-24):4436-45.
43. Aftyka A, Rybojad B, Rozalska-Walaszek I, Rzońca P, Humeniuk E. Post-traumatic stress disorder in parents of children hospitalized in the neonatal intensive care unit (NICU): medical and demographic risk factors. J Psychiatria Danubina. 2014;26(4):347-52.
44. Koliouli F, Gaudron CZ, Raynaud J-P. Stress, Coping, and Post-traumatic Stress Disorder of French Fathers of Premature Infants. Newborn and Infant Nursing Reviews. 2016;16(3):110-4.
45. Lefkowitz DS, Baxt C, Evans JR. Prevalence and correlates of posttraumatic stress and postpartum depression in parents of infants in the Neonatal Intensive Care Unit (NICU). Journal of clinical psychology in medical settings. 2010;17(3):230-7.
46. Yaman S, Altay N. Posttraumatic stress and experiences of parents with a newborn in the neonatal intensive care unit. Journal of Reproductive and Infant Psychology. 2015;33(2):140-52.

47. Winter L, Colditz PB, Sanders MR, Boyd RN, Pritchard M, Gray PH, et al. Depression, posttraumatic stress and relationship distress in parents of very preterm infants. Archives of Women's Mental Health. 2018;21(4):445-51.

48. Pace CC, Anderson PJ, Lee KJ, Spittle AJ, Treyvaud K. Posttraumatic Stress Symptoms in Mothers and Fathers of Very Preterm Infants Over the First 2 Years. Journal of Developmental & Behavioral Pediatrics. 2020;41(8):612-8.

49. Horsch A, Jacobs I, Gilbert L, Favrod C, Schneider J, Morisod Harari M, et al. Impact of perinatal asphyxia on parental mental health and bonding with the infant: a questionnaire survey of Swiss parents. BMJ Paediatrics Open. 2017;1(1):e000059.

50. Weathers FW, Bovin MJ, Lee DJ, Sloan DM, Schnurr PP, Kaloupek DG, et al. The Clinician-Administered PTSD Scale for DSM–5 (CAPS-5): development and initial psychometric evaluation in military vgeterans. Psychological Assessment. 2018;30(3):383-95.

51. Garthus Niegel S, Benyamini Y, Horsch A. Editorial: perinatal mental health: expanding the focus to the family context. Front Psychiatry. 2021;12(7):719053.

52. Horsch A, Stuijfzand S. Intergenerational transfer of perinatal trauma-related consequences. Journal of Reproductive and Infant Psychology. 2019;37(3):221-3.

53. Fairbrother N, Janssen P, Antony MM, Tucker E, Young AH. Perinatal anxiety disorder prevalence and incidence. Journal of affective disorders. 2016;200:148-55.

54. Dikmen-Yildiz P, Ayers S, Phillips L. Depression, anxiety, PTSD and comorbidity in perinatal women in Turkey: a longitudinal population-based study. Midwifery. 2017;55:29-37.

55. Wenzel A, Haugen EN, Jackson LC, Brendle JR. Anxiety symptoms and disorders at eight weeks postpartum. Journal of Anxiety Disorders. 2005;19(3):295-311.

56. Agius A, Xuereb RB, Carrick-Sen D, Sultana R, Rankin J. The co-existence of depression, anxiety and post-traumatic stress symptoms in the perinatal period: a systematic review. Midwifery. 2016;36:70-9.

57. O'Hara MW, Swain AM. Rates and risk of postpartum depression—a meta-analysis. International review of psychiatry. 1996;8(1):37-54.

58. Gavin NI, Gaynes BN, Lohr KN, Meltzer-Brody S, Gartlehner G, Swinson T. Perinatal depression: a systematic review of prevalence and incidence. Obstetrics & Gynecology. 2005;106(5 Part 1):1071-83.

59. Söderquist J, Wijma B, Thorbert G, Wijma K. Risk factors in pregnancy for post-traumatic stress and depression after childbirth. BJOG: An International Journal of Obstetrics & Gynaecology. 2009;116(5):672-80.

60. Czarnocka J, Slade P. Prevalence and predictors of post-traumatic stress symptoms following childbirth. The British journal of clinical psychology. 2000;39(1):35-51.

61. Leeds L, Hargreaves I. The psychological consequences of childbirth. Journal of Reproductive and Infant Psychology. 2008;26(2):108-22.

62. Davies J, Slade P, Wright I, Stewart P. Posttraumatic stress symptoms following childbirth and mothers' perceptions of their infants. Infant Ment Health J. 2008;29(6):537-54.

63. Paulson JF, Bazemore SD. Prenatal and postpartum depression in fathers and its association with maternal depression: a meta-analysis. JAMA. 2010;303(19):1961-9.
64. Thiel F, Pittelkow M-M, Wittchen H-U, Garthus-Niegel S. The relationship between paternal and maternal depression during the perinatal period: a systematic review and meta-analysis. Frontiers in Psychiatry. 2020;11(1072).
65. World Health Organization. WHO recommendations on health promotion interventions for maternal and newborn health. 2015.
66. Goodman JH, Watson GR, Stubbs B. Anxiety disorders in postpartum women: a systematic review and meta-analysis. Journal of affective disorders. 2016;203:292-331.
67. Dennis C-L, Falah-Hassani K, Shiri R. Prevalence of antenatal and postnatal anxiety: systematic review and meta-analysis. The British Journal of Psychiatry. 2017;210(5):315-23.
68. Lin WC, Chang SY, Chen YT, Lee HC, Chen YH. Postnatal paternal involvement and maternal emotional disturbances: the effect of maternal employment status. Journal of affective disorders. 2017;219:9-16.
69. Flory JD, Yehuda R. Comorbidity between post-traumatic stress disorder and major depressive disorder: alternative explanations and treatment considerations. Dialogues in clinical neuroscience. 2015;17(2):141-50.
70. de Graaff LF, Honig A, van Pampus MG, Stramrood CA. Preventing post‐traumatic stress disorder following childbirth and traumatic birth experiences: a systematic review. Acta obstetricia et gynecologica Scandinavica. 2018;97(6):648-56.
71. Holmes EA, Grey N, Young KAD. Intrusive images and "hotspots" of trauma memories in posttraumatic stress disorder: an exploratory investigation of emotions and cognitive themes. Journal of behavior therapy and experimental psychiatry. 2005;36(1):3-17.
72. Iyadurai L, Visser RM, Lau-Zhu A, Porcheret K, Horsch A, Holmes EA, et al. Intrusive memories of trauma: a target for research bridging cognitive science and its clinical application. Clinical psychology review. 2018;69:67-82.
73. Ehlers A, Clark DM. A cognitive model of posttraumatic stress disorder. Behaviour research and therapy. 2000;38(4):319-45.
74. Brewin CR. Episodic memory, perceptual memory, and their interaction: foundations for a theory of posttraumatic stress disorder. Psychol Bulletin. 2014;140(1):69-97.
75. Brewin CR, Holmes EA. Psychological theories of posttraumatic stress disorder. Clinical psychology review. 2003;23(3):339-76.
76. O'Donnell ML, Elliott P, Lau W, Creamer M. PTSD symptom trajectories: from early to chronic response. Behaviour research and therapy. 2007;45(3):601-6.
77. Holmes EA, James EL, Coode-Bate T, Deeprose C. Can playing the computer game "Tetris" reduce the build-up of flashbacks for trauma? A proposal from cognitive science. PloS one. 2009;4(1):e4153.

78. Baddeley A. Working memory: looking back and looking forward. Nature Reviews Neuroscience. 2003;4(10):829-39.
79. McGaugh JL. Memory-a Century of Consolidation. Science. 2000;287(5451):248-51.
80. Walker MP, Brakefield T, Hobson JA, Stickgold R. Dissociable stages of human memory consolidation and reconsolidation. Nature. 2003;425(6958):616-20.
81. Holmes EA, James EL, Kilford EJ, Deeprose C. Key steps in developing a cognitive vaccine against traumatic flashbacks: visuospatial Tetris versus verbal Pub Quiz. PloS one. 2010;5(11):e13706.
82. McGaugh JL. Memory - a century of consolidation. Science. 2000;287(5451):248-51.
83. Nader K, Schafe GE, LeDoux JE. The labile nature of consolidation theory. Nature Reviews Neuroscience. 2000;1(3):216-9.
84. Lau-Zhu A, Holmes EA, Butterfield S, Holmes J. Selective association between Tetris game play and visuospatial working memory: a preliminary investigation. Applied Cognitive Psychology. 2017;31(4):438-45.
85. Dewar MT, Cowan N, Sala SD. Forgetting due to retroactive interference: a fusion of Müller and Pilzecker's (1900) early insights into everyday forgetting and recent research on anterograde amnesia. Cortex; a journal devoted to the study of the nervous system and behavior. 2007;43(5):616-34.
86. Iyadurai L, Blackwell SE, Meiser-Stedman R, Watson PC, Bonsall MB, Geddes JR, et al. Preventing intrusive memories after trauma via a brief intervention involving Tetris computer game play in the emergency department: a proof-of-concept randomized controlled trial. Molecular psychiatry. 2018;23(3):674-82.
87. Hagenaars MA, Holmes EA, Klaassen F, Elzinga B. Tetris and Word games lead to fewer intrusive memories when applied several days after analogue trauma. European journal of psychotraumatology. 2017;8:1386959.
88. Kessler H, Schmidt A-C, James EL, Blackwell SE, von Rauchhaupt M, Harren K, et al. Visuospatial computer game play after memory reminder delivered three days after a traumatic film reduces the number of intrusive memories of the experimental trauma. Journal of behavior therapy and experimental psychiatry. 2020;67:101454.
89. James EL, Bonsall MB, Hoppitt L, Tunbridge EM, Geddes JR, Milton AL, et al. Computer Game Play Reduces Intrusive Memories of Experimental Trauma via Reconsolidation-Update Mechanisms. Psychological science. 2015;26(8):1201-15.
90. Kanstrup M, Singh L, Göransson KE, Widoff J, Taylor RS, Gamble B, et al. Reducing intrusive memories after trauma via a brief cognitive task intervention in the hospital emergency department: an exploratory pilot randomised controlled trial. Translational Psychiatry. 2021;11(1):30.
91. Ehlert U, Gaab J, Heinrichs M. Psychoneuroendocrinological contributions to the etiology of depression, posttraumatic stress disorder, and stress-related bodily disorders: the role of the hypothalamus–pituitary–adrenal axis. Biological psychology. 2001;57:141-52.
92. Nagpal M, Gleichauf K, Ginsberg J. Meta-analysis of heart rate variability as a psychophysiological indicator of posttraumatic stress disorder. Trauma & Treatment. 2013;3(1):1000182.

93. Del Giudice M, Ellis BJ, Shirtcliff EA. The Adaptive Calibration Model of stress responsivity. Neuroscience & Biobehavioral Reviews. 2011;35(7):1562-92.
94. Jansen AS, Van Nguyen X, Karpitskiy V, Mettenleiter TC, Loewy AD. Central Command Neurons of the Sympathetic Nervous System: Basis of the Fight-or-Flight Response. Science. 1995;270(5236):644-6.
95. Finan PH, Zautra AJ, Wershba R. The dynamics of emotions in adaptation to stress. In: Contrada RJ, Baum A, editors. The Handbook of Stress Science: Biology, Psychology, and Health. New York: Springer Publishing Company; 2011. p. 209-20.
96. Kudielka BM, Hellhammer DH, Kirschbaum C. Ten years of research with the Trier Social Stress Test - revisited. In: Harmon-Jones E, P. Winkielman P, editors. Social neuroscience: Integrating biological and psychological explanations of social behavior. New York, NY: The Guilford Press; 2007. p. 56-83.
97. Benfield RD, Newton ER, Tanner CJ, Heitkemper MM. Cortisol as a biomarker of stress in term human labor: physiological and methodological issues. Biological Research For Nursing. 2014;16(1):64-71.
98. Miller N, Asali AA, Agassi-Zaitler M, Neumark E, Eisenberg MM, Hadi E, et al. Physiological and psychological stress responses to labor and delivery as expressed by salivary cortisol: a prospective study. American journal of obstetrics and gynecology. 2019;221(4):351.e1-.e7.
99. Falk-Smith NL, Madrigal L. Maternal stress, anxiety, and fear of childbirth among planned homebirth mothers: results from a mixed methods study. The 88th Annual Meeting of the American Association of Physical Anthropologists; 27 March 2019; Cleveland, OH, USA2019. p. 71-2.
100. Heinrichs M, Neumann I, Ehlert U. Lactation and stress: protective effects of breast-feeding in humans. Stress. 2002;5(3):195-203.
101. Dickerson SS, Kemeny ME. Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. Psychological bulletin. 2004;130(3):355-91.
102. Allen AP, Kennedy PJ, Dockray S, Cryan JF, Dinan TG, Clarke G. The Trier Social Stress Test: Principles and practice. Neurobiology of stress. 2017;6:113-26.
103. Kirschbaum C, Pirke K-M, Hellhammer DH. The 'Trier Social Stress Test'–a tool for investigating psychobiological stress responses in a laboratory setting. Neuropsychobiology. 1993;28(1-2):76-81.
104. Pitman RK, Rasmusson AM, Koenen KC, Shin LM, Orr SP, Gilbertson MW, et al. Biological studies of post-traumatic stress disorder. Nature Reviews Neuroscience. 2012;13(11):769-87.
105. Miller GE, Chen E, Zhou ES. If it goes up, must it come down? Chronic stress and the hypothalamic-pituitary-adrenocortical axis in humans. Psychological bulletin. 2007;133(1):25-45.
106. England-Mason G, Kimber M, Khoury J, Atkinson L, MacMillan H, Gonzalez A. Difficulties with emotion regulation moderate the association between childhood history of maltreatment and cortisol reactivity to psychosocial challenge in postpartum women. Hormones and behavior. 2017;95:44-56.
107. Pierce ME, Pritchard LM. Lower stress-reactive cortisol in female veterans associated with military status but not PTSD. Stress. 2016;19(5):486-91.
108. Elzinga BM, Schmahl CG, Vermetten E, Van Dyck R, Bremner JD. Higher cortisol levels following exposure to traumatic reminders in abuse-related PTSD. Neuropsychopharmacology. 2003;28:1656-65.

109. Cordero MI, Moser DA, Manini A, Suardi F, Sancho-Rossignol A, Torrisi R, et al. Effects of interpersonal violence-related post-traumatic stress disorder (PTSD) on mother and child diurnal cortisol rhythm and cortisol reactivity to a laboratory stressor involving separation. Hormones and behavior. 2017;90:15-24.
110. Shaffer F, McCraty R, Zerr CL. A healthy heart is not a metronome: an integrative review of the heart's anatomy and heart rate variability. Frontiers in Psychology. 2014;5(1040).
111. Klinkenberg AV, Nater UM, Nierop A, Bratsikas A, Zimmermann R, Ehlert U. Heart rate variability changes in pregnant and non pregnant women during standardized psychosocial stress. Acta obstetricia et gynecologica Scandinavica. 2009;88(1):77-82.
112. Shaffer F, Ginsberg JP. An overview of heart rate variability metrics and norms. Frontiers in public health. 2017;5:258.
113. Campbell AA, Wisco BE, Silvia PJ, Gay NG. Resting respiratory sinus arrhythmia and posttraumatic stress disorder: a meta-analysis. Biological Psychology. 2019;144:125-35.
114. Schneider M, Schwerdtfeger A. Autonomic dysfunction in posttraumatic stress disorder indexed by heart rate variability: a meta-analysis. Psychological Medicine. 2020;50(12):1937-48.
115. Mason JW. A review of psychoendocrine research on the pituitary-adrenal cortical system. Psychosomatic medicine. 1968;30(5):576-607.
116. Ayers S, Crawley R, Webb R, Button S, Thornton A, the HABiT collaborative group. What are women stressed about after birth? Birth. 2019;46(4):678-85.
117. Meyer T, Albrecht J, Bornschein G, Sachsse U, Herrmann-Lingen C. Posttraumatic Stress Disorder (PTSD) patients exhibit a blunted parasympathetic response to an emotional stressor. Applied Psychophysiology and Biofeedback. 2016;41(4):395-404.
118. Trakhtenberg EC. The effects of guided imagery on the immune system: a critical review. International Journal of Neuroscience. 2008;118(6):839-55.
119. Messerli-Bürgy N, Kakebeeke TH, Arhab A, Stülb K, Zysset AE, Leeger-Aschmann CS, et al. The Swiss Preschoolers' health study (SPLASHY): objectives and design of a prospective multi-site cohort study assessing psychological and physiological health in young children. BMC Pediatrics. 2016;16(1):1-16.
120. Cook F, Conway L, Gartland D, Giallo R, Keys E, Brown SA. Profiles and predictors of infant sleep problems across the first year. Journal of Developmental & Behavioral Pediatrics. 2020;41(2):104-16.
121. Stuijfzand S, Garthus-Niegel S, Horsch A. Parental birth-related PTSD symptoms and bonding in the early postpartum period: a prospective population-based cohort study. Frontiers in psychiatry. 2020;11.
122. Gutierrez-Galve L, Stein A, Hanington L, Heron J, Lewis G, O'Farrelly C, et al. Association of Maternal and Paternal Depression in the Postnatal Period With Offspring Depression at Age 18 Years. JAMA psychiatry. 2019;76(3):290-6.
123. Gutierrez-Galve L, Stein A, Hanington L, Heron J, Ramchandani P. Paternal Depression in the Postnatal Period and Child Development: Mediators and Moderators. Pediatrics. 2015;135(2):e339.

124. Garthus-Niegel S, Ayers S, Martini J, Von Soest T, Eberhard-Gran M. The impact of postpartum post-traumatic stress disorder symptoms on child development: a population-based, 2-year follow-up study. Psychological medicine. 2017;47(1):161-70.

125. Garthus-Niegel S, Horsch A, Ayers S, Junge-Hoffmeister J, Weidner K, Eberhard-Gran M. The influence of postpartum PTSD on breastfeeding: a longitudinal population-based study. Birth. 2018;45(2):193-201.

126. Garthus-Niegel S, Horsch A, Bickle Graz M, Martini J, von Soest T, Weidner K, et al. The prospective relationship between postpartum PTSD and child sleep: A 2-year follow-up study. Journal of affective disorders. 2018;241:71-9.

127. Bauer A, Parsonage M, Knapp M, Iemmi V, Adelaja B. The costs of perinatal mental health problems. London: Centre for Mental Health and London School of Economics; 2014.

128. Bowers ME, Yehuda R. Intergenerational Transmission of Stress in Humans. Neuropsychopharmacology. 2016;41(1):232-44.

129. Cook N, Ayers S, Horsch A. Maternal posttraumatic stress disorder during the perinatal period and child outcomes: a systematic review. Journal of affective disorders. 2018;225:18-31.

130. Ip S, Chung M, Raman G, Chew P, Magula N, DeVine D, et al. Breastfeeding and maternal and infant health outcomes in developed countries. Evidence report/technology assessment. 2007;153:1-186.

131. Nakić Radoš S, Matijaš M, Anđelinović M, Čartolovni A, Ayers S. The role of posttraumatic stress and depression symptoms in mother-infant bonding. Journal of affective disorders. 2020;268:134-40.

132. Kjerulff KH, Attanasio LB, Sznajder KK, Brubaker LH. A prospective cohort study of post-traumatic stress disorder and maternal-infant bonding after first childbirth. Journal of Psychosomatic Research. 2021;144:110424.

133. Mayopoulos GA, Ein-Dor T, Dishy GA, Nandru R, Chan SJ, Hanley LE, et al. COVID-19 is associated with traumatic childbirth and subsequent mother-infant bonding problems. Journal of affective disorders. 2021;282:122-5.

134. Yehuda R, Bierer LM. The relevance of epigenetics to PTSD: implications for the DSM-V. J Trauma Stress. 2009;22(5):427-34.

135. Hysing M, Sivertsen B, Garthus-Niegel S, Eberhard-Gran M. Pediatric sleep problems and social-emotional problems. A population-based study. Infant Behavior and Development. 2016;42:111-8.

136. Spruyt K. A review of developmental consequences of poor sleep in childhood. Sleep Medicine. 2019;60:3-12.

137. Lam P, Hiscock H, Wake M. Outcomes of infant sleep problems: a longitudinal study of sleep, behavior, and maternal well-being. Pediatrics. 2003;111(3):e203-e7.

138. Teti DM, Crosby B. Maternal depressive symptoms, dysfunctional cognitions, and infant night waking: the role of maternal nighttime behavior. Child Development. 2012;83(3):939-53.

139. Piteo AM, Roberts RM, Nettelbeck T, Burns N, Lushington K, Martin AJ, et al. Postnatal depression mediates the relationship between infant and maternal sleep disruption and family dysfunction. Early Hum Dev. 2013;89(2):69-74.

140. Davis KF, Parker KP, Montgomery GL. Sleep in infants and young children: part one: normal sleep. Journal of Pediatric Health Care. 2004;18(2):65-71.
141. Henderson JMT, France KG, Blampied NM. The consolidation of infants' nocturnal sleep across the first year of life. Sleep Medicine Reviews. 2011;15(4):211-20.
142. Hiscock H. Rock-a-bye baby? Parenting and infant sleep. Sleep Medicine Reviews. 2010;14(2):85-7.
143. Sadeh A, Anders TF. Infant sleep problems: origins, assessment, interventions. Infant Ment Health J. 1993;14(1):17-34.
144. Sadeh A, Tikotzky L, Scher A. Parenting and infant sleep. Sleep Med Rev. 2010;14(2):89-96.
145. Sadeh A. A brief screening questionnaire for infant sleep problems: validation and findings for an Internet sample. Pediatrics. 2004;113(6):e570-e7.
146. Williamson AA, Mindell JA, Hiscock H, Quach J. Child sleep behaviors and sleep problems from infancy to school-age. Sleep Medicine. 2019;63:5-8.
147. Byars KC, Yolton K, Rausch J, Lanphear B, Beebe DW. Prevalence, patterns, and persistence of sleep problems in the first 3 years of life. Pediatrics. 2012;129(2):e276-84.
148. Kahn A, Mozin MJ, Rebuffat E, Sottiaux M, Muller MF. Milk intolerance in children with persistent sleeplessness: a prospective double-blind crossover evaluation. Pediatrics. 1989;84(4):595-603.
149. Dias CC, Figueiredo B. Mother's prenatal and postpartum depression symptoms and infant's sleep problems at 6 months. Infant Ment Health J. 2020;41(5):614-27.
150. Petzoldt J, Wittchen HU, Einsle F, Martini J. Maternal anxiety versus depressive disorders: specific relations to infants' crying, feeding and sleeping problems. Child Care Health Dev. 2016;42(2):231-45.
151. Richter N, Reck C. Positive maternal interaction behavior moderates the relation between maternal anxiety and infant regulatory problems. Infant Behav Dev. 2013;36(4):498-506.
152. Pierrehumbert B, Nicole A, Muller-Nix C, Forcada-Guex M, Ansermet F. Parental post-traumatic reactions after premature birth: implications for sleeping and eating problems in the infant. Arch Dis Child Fetal Neonatal 2003;88(5):F400-F4.
153. Kim Y, Bird A, Peterson E, Underwood L, Morton SMB, Grant CC. Maternal antenatal depression and early childhood sleep: potential pathways through infant temperament. J Pediatr Psychol. 2020;45(2):203-17.
154. Parade SH, Wong K, Belair R, Dickstein S, Seifer R. Infant sleep moderates the effect of infant temperament on maternal depressive symptoms, maternal sensitivity, and family functioning. Infant Behavior and Development. 2019;57.
155. Field T. Infant sleep problems and interventions: a review. Infant Behavior and Development. 2017;47:40-53.
156. Morrell J, Steele H. The role of attachment security, temperament, maternal perception, and care-giving behavior in persistent infant sleeping problems. Infant Mental Health Journal. 2003;24(5):447-68.
157. Tikotzky L, Sadeh A. Maternal sleep-related cognitions and infant sleep: a longitudinal study from pregnancy through the 1st year. Child Development. 2009;80(3):860-74.

158. Burdayron R, Butler BP, Béliveau M-J, Dubois-Comtois K, Pennestri M-H. Perception of infant sleep problems: the role of negative affectivity and maternal depression. Journal of clinical sleep medicine. 2021;17(6):1279-85.

159. Sandoz V, Deforges C, Stuijfzand S, Epiney M, Vial Y, Sekarski N, et al. Improving mental health and physiological stress responses in mothers following traumatic childbirth and in their infants: study protocol for the Swiss TrAumatic biRth Trial (START). BMJ Open. 2019;9(12):e032469.

160. Foa EB, Cashman L, Jaycox L, Perry K. The validation of a self-report measure of posttraumatic stress disorder: the Posttraumatic Diagnostic Scale. Psychological assessment. 1997;9(4):445-51.

161. Furuta M, Horsch A, Ng ES, Bick D, Spain D, Sin J. Effectiveness of trauma-focused psychological therapies for treating post-traumatic stress disorder symptoms in women following childbirth: a systematic review and meta-analysis. Frontiers in psychiatry. 2018;9.

162. Roberts NP, Kitchiner NJ, Kenardy J, Bisson JI. Multiple session early psychological interventions for the prevention of post-traumatic stress disorder. Cochrane Database of Systematic Reviews. 2009.

163. Sijbrandij M, Kleiboer A, Bisson JI, Barbui C, Cuijpers P. Pharmacological prevention of post-traumatic stress disorder and acute stress disorder: a systematic review and meta-analysis. The Lancet Psychiatry. 2015;2(5):413-21.

164. Rose SC, Bisson J, Churchill R, Wessely S. Psychological debriefing for preventing post traumatic stress disorder (PTSD). Cochrane Database of Systematic Reviews. 2002;2:CD000560.

165. Blevins CA, Weathers FW, Davis MT, Witte TK, Domino JL. The posttraumatic stress disorder checklist for DSM 5 (PCL 5): Development and initial psychometric evaluation. Journal of Traumatic Stress. 2015;28(6):489-98.

166. Sandoz V, Stuijfzand S, Lacroix A, Deforges C, Quillet Diop M, Ehlert U, et al. The Lausanne Infant Crying Stress Paradigm: validation of an early postpartum stress paradigm with women at low- vs. high-risk of childbirth-related posttraumatic stress disorder. J Pers Med. 2021;11(6):472.

167. Allen AP, Kennedy PJ, Cryan JF, Dinan TG, Clarke G. Biological and psychological markers of stress in humans: focus on the Trier Social Stress Test. Neuroscience & Biobehavioral Reviews 2014;38:94-124.

168. R Development Core Team. R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2019.

169. Van Buuren S, Groothuis-Oudshoorn K. MICE: multivariate imputation by chained equations in R. Journal of statistical software. 2011;45(3):1-68.

170. Sandoz V, Lacroix A, Stuijfzand S, Bickle Graz M, horsch A. The distinct influence of different maternal mental health symptom profiles on infant sleep during the first year postpartum: a cross-sectional survey. Submitted to Early Human Development.

171. Sandoz V, Hingray C, Stuijfzand S, Lacroix A, El Hage W, Horsch A. Measurement and conceptualization of maternal PTSD following childbirth: psychometric properties of the City Birth Trauma Scale – French version (City BiTS-F). Psychological Trauma: Theory, Research, Practice, and Policy. 2021.

172. Putnam SP, Helbig AL, Gartstein MA, Rothbart MK, Leerkes E. Development and Assessment of Short and Very Short Forms of the Infant Behavior Questionnaire–Revised. Journal of Personality Assessment. 2014;96(4):445-58.

173. Wild D, Grove A, Martin M, Eremenco S, McElroy S, Verjee-Lorenz A, et al. Principles of Good Practice for the Translation and Cultural Adaptation Process for Patient-Reported Outcomes (PRO) Measures: report of the ISPOR Task Force for Translation and Cultural Adaptation. Value in health. 2005;8(2):94-104.

174. Cox JL, Holden JM, Sagovsky R. Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. The British journal of psychiatry. 1987;150(6):782-6.

175. Guedeney N, Fermanian J. Validation study of the French version of the Edinburgh Postnatal Depression Scale (EPDS): new results about use and psychometric properties. European psychiatry. 1998;13(2):83-9.

176. Zigmond AS, Snaith RP. The Hospital Anxiety and Depression Scale. Acta psychiatrica scandinavica. 1983;67(6):361-70.

177. Bocéréan C, Dupret E. A validation study of the Hospital Anxiety and Depression Scale (HADS) in a large sample of French employees. BMC Psychiatry. 2014;14(1):354.

178. Giles GE, Mahoney CR, Brunyé TT, Taylor HA, Kanarek RB. Stress effects on mood, HPA axis, and autonomic response: comparison of three psychosocial stress paradigms. PloS one. 2014;9(12):e113618-e.

179. Heinrichs M, Baumgartner T, Kirschbaum C, Ehlert U. Social support and oxytocin interact to suppress cortisol and subjective responses to psychosocial stress. Biological Psychiatry 2003;54(12):1389-98.

180. Wright KP, Drake AL, Frey DJ, Fleshner M, Desouza CA, Gronfier C, et al. Influence of sleep deprivation and circadian misalignment on cortisol, inflammatory markers, and cytokine balance. Brain, Behavior, and Immunity. 2015;47:24-34.

181. Almanza-Sepulveda ML, Fleming AS, Jonas W. Mothering revisited: A role for cortisol? Hormones and behavior. 2020;121:104679.

182. Lawrence RA, Lawrence RM. Physiology of lactation. In: Lawrence RA, Lawrence RM, editors. Breastfeeding (Seventh Edition). . Philadelphia: W.B. Saunders; 2011. p. 62-97.

183. Kaye J, Soothill P, Hunt M, Lightman S. Responses to the 35% CO challenge in postpartum women. Clin Endocrinol (Oxf). 2004;61(5):582-8.

184. Terkelsen AJ, Mølgaard H, Hansen J, Andersen OK, Jensen TS. Acute pain increases heart rate: Differential mechanisms during rest and mental stress. Autonomic Neuroscience. 2005;121(1):101-9.

185. Eisenach JC, Pan PH, Smiley R, Lavand'homme P, Landau R, Houle TT. Severity of acute pain after childbirth, but not type of delivery, predicts persistent pain and postpartum depression. PAIN. 2008;140(1):87-94.

186. Schechter DS, Moser DA, McCaw JE, Myers MM. Autonomic functioning in mothers with interpersonal violence-related posttraumatic stress disorder in response to separation–reunion. Developmental Psychobiology. 2014;56(4):748-60.

187. Sechi C, Vismara L, Rollè L, Prino LE, Lucarelli L. First-Time Mothers' and Fathers' Developmental Changes in the Perception of Their Daughters' and Sons' Temperament: Its Association With Parents' Mental Health. Front Psychol. 2020;11.

188. McMahon C, Barnett B, Kowalenko N, Tennant C, Don N. Postnatal Depression, Anxiety and Unsettled Infant Behaviour. Australian & New Zealand Journal of Psychiatry. 2001;35(5):581-8.

189. Cornish AM, McMahon CA, Ungerer JA, Barnett B, Kowalenko N, Tennant C. Maternal depression and the experience of parenting in the second postnatal year. Journal of Reproductive and Infant Psychology. 2006;24(2):121-32.

190. Sadeh A, Flint-Ofir E, Tirosh T, Tikotzky L. Infant sleep and parental sleep-related cognitions. Journal of family psychology. 2007;21(1):74-87.

191. Thirion M, Challamel M-J. Le sommeil, le rêve et l'enfant. Paris, France: Albin Michel; 2011.

192. Magarey A, Kavian F, Scott JA, Markow K, Daniels L. Feeding mode of Australian infants in the first 12 months of life: an assessment against national breastfeeding indicators. Journal of Human Lactation. 2015;32(4):NP95-NP104.

193. Lorant V, Deliège D, Eaton W, Robert A, Philippot P, Ansseau M. Socioeconomic inequalities in depression: a meta-analysis. American Journal of Epidemiology. 2003;157(2):98-112.

194. Warren SL, Gunnar MR, Kagan J, Anders TF, Simmens SJ, Rones M, et al. Maternal panic disorder: infant temperament, neurophysiology, and parenting behaviors. Journal of the American Academy of Child & Adolescent Psychiatry. 2003;42(7):814-25.

195. Brewin CR, Andrews B, Valentine JD. Meta-analysis of risk factors for posttraumatic stress disorder in trauma-exposed adults. Journal of Consulting and Clinical Psychology. 2000;68(5):748-66.

196. Ozer EJ, Best SR, Lipsey TL, Weiss DS. Predictors of posttraumatic stress disorder and symptoms in adults: a meta-analysis. Psychological bulletin. 2003;129(1):52-73.

197. Thoits PA. Mechanisms linking social ties and support to physical and mental health. Journal of health and social behavior. 2011;52(2):145-61.

198. Woodhouse S, Brown R, Ayers S. A social model of posttraumatic stress disorder: interpersonal trauma, attachment, group identification, disclosure, social acknowledgement, and negative cognitions. Journal of Theoretical Social Psychology. 2018;2(2):35-48.

199. Cowan PA, Cowan CP. Normative family transitions, couple relationship quality, and healthy child development. In: Walsh F, editor. Normal family processes: growing diversity and complexity. 4 ed. New York, US: The Guilford Press; 2012. p. 428-51.

200. De Geest S, Zúñiga F, Brunkert T, Deschodt M, Zullig LL, Wyss K, et al. Powering Swiss health care for the future: implementation science to bridge "the valley of death". J Swiss Medical Weekly. 2020;150(3738).

201. Balas EA, Boren SA. Managing Clinical Knowledge for Health Care Improvement. Yearb Med Inform. 2000;09(01):65-70.

202. Hupbach A, Hardt O, Gomez R, Nadel L. The dynamics of memory: context-dependent updating. Learning & Memory. 2008;15(8):574-9.

203. Treanor M, Brown LA, Rissman J, Craske MG. Can Memories of Traumatic Experiences or Addiction Be Erased or Modified? A Critical Review of Research on the Disruption of Memory Reconsolidation and Its Applications. Perspectives on Psychological Science. 2017;12(2):290-305.

204. Warren SL, Howe G, Simmens SJ, Dahl RE. Maternal depressive symptoms and child sleep: models of mutual influence over time. Development psychopathology. 2006;18(1):1-16.

205. El-Sheikh M, Kelly RJ, Bagley EJ, Wetter EK. Parental depressive symptoms and children's sleep: the role of family conflict. Journal of Child Psychology

Psychiatry. 2012;53(7):806-14.

206. Ystrom E, Hysing M, Torgersen L, Ystrom H, Reichborn-Kjennerud T, Sivertsen B. Maternal Symptoms of Anxiety and Depression and Child Nocturnal Awakenings at 6 and 18 Months. J Pediatr Psychol. 2017;42(10):1156-64.

207. Dias CC, Figueiredo B. Unidirectional and bidirectional links between maternal depression symptoms and infant sleep problems. 2021:e13363.

208. Tetzlaff JM, Chan A-W, Kitchen J, Sampson M, Tricco AC, Moher D. Guidelines for randomized clinical trial protocol content: a systematic review. Systematic Reviews. 2012;1(43).

209. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Annals of Internal Medicine. 2007;147(8):573-7.

210. Osanloo A, Grant CC. Understanding, selecting, and integrating a theoretical framework in dissertation research: creating the blueprint for your "house". Administrative issues journal: connecting education, practice, and research. 2014;4(2):12-26.

211. Adom D, Hussein EK, Agyem JA. Theoretical and conceptual framework: mandatory ingredients of a quality research. International Journal of Scientific Research. 2018;7(1):6-9.

212. Wobbrock JO, Findlater L, Gergle D, Higgins JJ. The aligned rank transform for nonparametric factorial analyses using only anova procedures. Proceedings of CHI 2011 Conference on Human Factors in Computing Systems. 2011:143–6.

213. PubMed. ("Parturition"[Mesh]) AND "Stress Disorders, Traumatic"[Mesh] - Search Results - PubMed: National Library of Medicine; n.d. [Available from: https://pubmed.ncbi.nlm.nih.gov/?sort=date&term=(%22Parturition%22%5BMesh%5D)+AND+%22Stress+Disorders%2C+Traumatic%22%5BMesh%5D.

214. Brazelton TB, Nugent JK. The Neontal Behavioral Assessment Scale. 4th ed. London: Mac Keith Press; 2011.

215. Bayley N, Reuner G. Bayley scales of infant and toddler development: Bayley-III. San Antonio, Texas, USA: Harcourt Assessment, Psych. Corporation; 2006.

216. Stein A, Woolley H, Cooper SD, Fairburn CG. An Observational Study of Mothers with Eating Disorders and Their Infants. Journal of Child Psychology and Psychiatry. 1994;35(4):733-48.

217. Wolke D, Skuse D, Mathiasen B. Behavioral style in failure-to-thrive infants: a preliminary communication. Journal of pediatric psychology. 1990;15(2):237-54.

218. Skuse D, Wolke D, Reilly S. Failure to thrive: Clinical and developmental aspects. Developmental psychopathology. 1992: 46–71.

7. Publication list

Published articles in peer reviewed journals

1. **Sandoz V,** Hingray C, Stuijfzand S, Lacroix A, El Hage W*, Horsch A* (*joint authors). Measurement and conceptualization of maternal PTSD following childbirth: Psychometric properties of the City Birth Trauma Scale – French version (City BiTS-F). Psychological Trauma: Theory, Research, Practice, and Policy. 2021.
2. **Sandoz V[2],** Stuijfzand S, Lacroix A, Deforges C, Quillet Diop M, Ehlert U, et al. The Lausanne Infant Crying Stress Paradigm: Validation of an Early Postpartum Stress Paradigm with Women at Low- vs. High-Risk of Childbirth-related Posttraumatic Stress Disorder. J Pers Med. 2021;11(6):472.
3. Stuijfzand S, Deforges C, **Sandoz V,** Sajin C T, Jaques C, Elmers J, Horsch A. Psychological Impact of an Epidemic/Pandemic on the Mental Health of Healthcare Professionals: A Rapid Review. BMC Public Health. 2020:20(1):1-18.
4. **Sandoz V[2],** Deforges C, Stuijfzand S, Epiney M, Vial Y, Sekarski N, et al. Improving mental health and physiological stress responses in mothers following traumatic childbirth and in their infants: study protocol for the Swiss TrAumatic biRth Trial (START). BMJ Open. 2019;9(12):e032469.
5. **Sandoz V,** Bickle-Graz M, Camos V, Horsch A. Maternal postpartum depression symptoms are negatively associated with emotion regulation of children born very preterm. Acta paediatrica. 2019;108(5):969-70.

Submitted and under reviewed articles in peer-reviewed journals

1. **Sandoz V[2],** Lacroix A, Stuijfzand S, Bickle-Graz M, Horsch A. The distinct influence of different maternal mental health symptom profiles on infant sleep during the first year postpartum: a cross-sectional survey. Early Human Development. Submitted
2. Duroux M, Stuijfzand S, **Sandoz V,** Horsch A. Investigating prenatal perceived support as protective factor against adverse birth outcomes: A community cohort study. Journal of Reproductive and Infant Psychology. Under review.
3. Schneider J, **Sandoz V,** Equey L, Williams-Smith J, Horsch A, Bickle Graz M. Do preschool children identify the emotions of facemask wearing adults? JAMA Pediatrics. Under review.

Published article in non-peer reviewed journal

1. Deforges C, **Sandoz V,** Horsch A. Le trouble de stress post-traumatique lié à l'accouchement. Revue de Médecine Périnatale. 2020.

[2] Articles related to this thesis

Published data set

1. **Sandoz V,** Horsch A. Dataset of Measurement and conceptualization of maternal PTSD following childbirth: Psychometric properties of the City Birth Trauma Scale – French version (City BiTS-F). Zenodo; 2021.
2. **Sandoz V,** Horsch A. Dataset of The distinct influence of different maternal mental health symptom profiles on infant sleep during the first year postpartum: a cross-sectional survey. Zenodo; 2021.

8. Appendices

8.1. Appendix A

Improving mental health and physiological stress responses in mothers following traumatic childbirth and in their infants: Study protocol for the Swiss TrAumatic biRth Trial (START)[3]

Vania Sandoz[1], Camille Deforges[1], Suzannah Stuijfzand[1], Manuella Epiney[2], Yvan Vial[3], Nicole Sekarski[4], Nadine Messerli, U Ehlert[6], Myriam Bickle-Graz[7], Mathilde Morisod Harari[8], Kate Porcheret[9], Daniel S. Schechter[10,11], Susan Ayers[12], Emily A. Holmes[13], & Antje Horsch[1,7*] on behalf of the *START Research Consortium*

[1]Institute of Higher Education and Research in Healthcare (IUFRS), University of Lausanne, Lausanne, Switzerland

[2]Department Woman-Child-Adolescent, Geneva University Hospital and University of Geneva, Geneva, Switzerland.

[3]Obstetrics and Gynecology Service, Woman-Mother-Child Department, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland

[4]Paediatric Cardiology Unit, Woman-Mother-Child Department, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland

[5]Clinical Child Psychology & Biological Psychology, University of Fribourg, Fribourg, Switzerland

[6]Department of Clinical Psychology and Psychotherapy, University of Zurich, Zurich, Switzerland

[7]Neonatology Service, Woman-Mother-Child Department, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland

[8]Service of Child and Adolescent Psychiatry, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland

[9]Turner Institute for Brain and Mental Health, Monash University, Australia

[10]University Hospital of Lausanne, Service of Child and Adolescent Psychiatry Lausanne, Lausanne, Switzerland

[11]Department of Psychiatry, University of Geneva Faculty of Medicine, Geneva, Switzerland

[12]Centre for Maternal and Child Health Research, School of Health Sciences, City, University of London, London, UK

[13]Department of Psychology, Uppsala University, Uppsala, Sweden

Email addresses:

Vania.Sandoz@bluewin.ch

Camille.Deforges@chuv.ch

Suzannah.Ravenscroft@chuv.ch

Manuella.Epiney@hcuge.ch

[3] Sandoz V, Deforges C, Stuijfzand S, Epiney M, Vial Y, Sekarski N, et al. Improving mental health and physiological stress responses in mothers following traumatic childbirth and in their infants: study protocol for the Swiss TrAumatic biRth Trial (START). BMJ Open. 2019;9(12):e032469

Yvan.Vial@chuv.ch
Nicole.Sekarski@chuv.ch
Nadine.Messerli@unifr.ch
U.Ehlert@psychologie.uzh.ch
Myriam.Bickle-Graz@chuv.ch
Mathilde.Morisod@chuv.ch
Kate.Porcheret@monash.edu
Daniel.Schechter@chuv.ch
Susan.Ayers.1@city.ac.uk
emily.holmes@psyk.uu.se
Antje.Horsch@chuv.ch

***Corresponding author:**

Prof. Antje Horsch, Institute of Higher Education and Research in Healthcare (IUFRS), University of Lausanne, SV-A, Route de la Corniche 10, 1010 Lausanne.

Phone: 00 41 21 314 85 71. Antje.Horsch@chuv.ch

Keywords: early intervention, PTSD, maternal mental health, infant development, HRV, cortisol, sleep, Bayley-III, trauma, mental imagery, intrusive memories

ABSTRACT

Introduction: Emergency caesarean section (ECS) qualifies as a psychological trauma, which may result in postnatal posttraumatic stress disorder (PTSD). Maternal PTSD may not only have a significant negative impact on mother-infant interactions, but also on long-term infant development. The partner's mental health may also affect infant development. Evidence-based early interventions to prevent the development of postpartum PTSD in mothers are lacking. Immediately after a traumatic event, memory formation is vulnerable to interference. There is accumulating evidence that a brief behavioural intervention including a visuospatial task may result in a reduction in intrusive memories of the trauma.

Methods and analysis: This study protocol describes a double-blind multi-centre randomised controlled phase III trial testing an early brief maternal intervention including the computer game "Tetris" on intrusive memories of the ECS trauma (1 week) and PTSD symptoms (6 weeks, primary outcome) of 144 women following an ECS. The intervention group will carry out a brief behavioural procedure including playing Tetris. The attention-placebo control group will complete a brief written activity log. Both simple cognitive tasks will be completed within the first 6 hours following traumatic childbirth. The intervention is delivered by midwives/nurses in the maternity unit. The primary outcome will be differences in the presence and severity of maternal PTSD symptoms between the intervention and the attention-placebo control group at 6 weeks postpartum. Secondary outcomes will be physiological stress and psychological vulnerability, mother-infant interaction, and infant developmental outcomes. Other outcomes will be psychological vulnerability and physiological regulation of the partner and their bonding with the infant, as well as the number of intrusive memories of the event.

Ethics and dissemination: Ethical approval was granted by the Human Research Ethics Committee of the Canton de Vaud (study number 2017-02142). Dissemination of results will occur via national and international conferences, in peer-reviewed journals, public conferences, and social media.

Trial registration number: *clinicaltrials.gov* (NCT 03576586)

ARTICLE SUMMARY

Strengths and limitations of this study

- This multi-centre RCT will test the effects of an early brief behavioural intervention carried out by midwives/nurses on the labour ward.
- The primary outcome will be the presence and severity of maternal PTSD symptoms at 6 weeks.
- The early brief intervention, conducted in the same hospital where the traumatic event occurred, includes a visuospatial task aimed at competing with sensory aspects of the traumatic memory before it has been fully consolidated.
- Methodological rigour, including a double-blind design, an active control group, concealment of random allocation, regular monitoring, and prospective trial registration, limits risk of bias.
- Some outcomes are measured with self-report questionnaires, which may induce a social desirability bias.

ABBREVIATIONS

ANS: Autonomic Nervous System / ASD: Acute Stress Disorder / ASDS: Acute Stress Disorder Scale / BSID-III: Bayley Scales of Infant Development, 3rd Edition / CAPS: Clinician-Administered PTSD Scale for DSM-5 / CAR: Cortisol Awakening Response / CRIB: Clinical Risk Index for Babies / EAS: Emotional Availability Scales / ECG: Electrocardiography / ECS: Emergency Caesarean Section / EPDS: Edinburgh Postnatal Depression Scale / FFSF: Face-to-Face Still-Face paradigm / HADS: Hospital Anxiety and Depression Scale / HPA: Hypothalamic-Pituitary-Adrenal / HRV: Heart Rate Variability / IBIs: Interbeat Intervals / IBQ-R: Infant Behavior Questionnaire-Revised / MEQ: Morningness-Eveningness Questionnaire / MIBS: Mother-to-Infant Bonding Scale / MOS-8: Modified Medical Outcomes Study Social Support Survey / NBAS: Neonatal Behavioural Assessment Scale / PCL-5: PTSD Checklist for DSM-5 / PDPSI: Post-delivery Perceived Stress Inventory / PPSI: Postnatal Perceived Stress Inventory / PSI-SF: Parenting Stress Index - Short Form / PSQI: Pittsburgh Sleep Quality Index / PSQI-A: Pittsburgh Sleep Quality Index Addendum / PTSD: Post-Traumatic Stress Disorder / RCT: Randomised Controlled Trial / RDAS: Revised Dyadic Adjustment Scale / START: Swiss Traumatic Birth Trial

INTRODUCTION

Childbirth and PTSD

Though childbirth is a common and often fulfilling event, one third of mothers rate their childbirth as traumatic(1). Childbirth can meet diagnostic criteria for a traumatic event, if women perceived their life and/or the life of their baby to be in danger(2). Posttraumatic stress disorder (PTSD) related to childbirth is diagnosable in around 3-4% of women(3, 4). PTSD consists of four symptom clusters (intrusions, avoidance, hyperarousal, and negative cognitions and mood) and can be diagnosed at least one month after the traumatic stressor occurred(2). Comparing different modes of childbirth, obstetric complications, such as emergency caesarean section (ECS) produce higher rates of postnatal PTSD (19-39%)(3). ECS is a relatively frequent event, and there is thus a need to better identify and support women who are vulnerable to developing PTSD following an ECS.

Postnatal PTSD can significantly influence the experience of subsequent pregnancies, with increased risk of maternal stress and its associated risks of intrauterine growth retardation, premature birth and low birth weight(5-7). It can lead to a fear of subsequent pregnancy and childbirth, sexual problems, and avoidance of medical care(8, 9). Postnatal PTSD can also have important negative consequences for breastfeeding, the attachment relationship with the baby and mother-infant interactions, with a subsequent detrimental impact on the development of the child, as well as for the couple relationship(7, 10-13). PTSD is also highly co-morbid with depression, for which there is substantial evidence of long-term negative effects on child development and behaviour(14-16). Estimated economic costs of perinatal mental health problems are about £8.1 billion for each one-year cohort of UK births, of which 72% relate to adverse impacts on the child rather than the mother(17). In Switzerland, 16.7% of women in the perinatal period used mental health services(18). New and innovative evidence-based interventions are therefore needed to reduce those costs by preventing the development of postnatal PTSD(19).

To date, research investigating PTSD symptoms in partners following ECS is missing. Most studies on partners so far have focused on postnatal depression reporting that 1-8% experience depression symptoms in the first 6 weeks and 5-6% at 3-6 months following childbirth without complications(20-22), with increased risk following high risk situations(23). In one study, 5% of partners reported severe intrusions and avoidance symptoms at 9 weeks postpartum(24). Although the influence of partner mental health is understudied, it also seems to negatively impact child outcomes(25-27). Thus, partner mental health needs to be better understood not only in order to help the partner but also to support family and child outcomes.

Physiological stress responses associated with PTSD

Traumatic exposure activates the hypothalamic-pituitary-adrenal (HPA) axis, a cascade-like hormonal system resulting in the release of cortisol from adrenal cortex cells in body fluids. In parallel, the organism activates the more rapidly mobilizing autonomic nervous system (ANS) resulting in the release of norepinephrine from nerve terminals of the sympathetic nervous system as well as epinephrine and norepinephrine from the adrenal medulla(28). While the HPA axis shows the above stress-related reactivity, it also shows a basal activity with circadian variations in the respective hormones. For instance, cortisol peaks 30-45 minutes after awakening

(the so-called CAR: cortisol awakening response) and gradually declines throughout the day with lowest levels early during sleep(29, 30).

Specific patterns of HPA axis functioning have been shown in PTSD(31) although this has so far not been studied after traumatic childbirth. While studies indicate that individuals with PTSD show different patterns of HPA axis functioning to those without PTSD, there is little consistency in the specificity of these patterns(32-38). A meta-analysis examining diurnal cortisol levels in adults with PTSD showed that low cortisol levels were not related to PTSD in general, but rather to trauma exposure and co-morbidities(39). Finally, a recent study in a postnatal population found a negative association between symptoms of re-experiencing and diurnal cortisol slopes in mothers of preterm children(40). Concerning cortisol reactivity to a subsequent stressor, again, results are discrepant(41, 42).

Although HPA axis reactivity following stress or trauma is thought to be adaptive, acute or chronic exposure to stress has been shown to have deleterious effects(43, 44). It may not only result in dysfunctions of HPA re-activity, but also in health-relevant changes in the basal activation of this system(45). Overall, these studies show the strong implication of the HPA axis dysregulation in the development and maintenance of PTSD, although studies in postnatal populations are scarce.

Reduced heart rate variability (HRV), an indicator of autonomic flexibility, has been found to be related to psychopathological processes(46). Individuals with PTSD show lower levels of HRV in comparison with trauma-exposed individuals without PTSD or healthy controls(47, 48). However, the relationship of PTSD and HRV has so far not been studied in a postnatal population.

Sleep in PTSD is also disrupted. Sleep disturbance (i.e., difficulty falling or staying asleep) and recurrent distressing dreams are both diagnostic criteria for PTSD(2), with 70-91% of patients with PTSD suffering from subjective sleep disturbances and 19-71% reporting nightmares(49). Findings from experimental research indicate that sleep on the first night after trauma may be important for the development of subsequent intrusive memories of the index trauma. One study found that totally sleep deprived participants reported *fewer* intrusive memories after a laboratory stressor compared to those who slept(50), though findings are mixed(51-53). Thus, it is important to assess sleep over time following a real world traumatic event, such as following an ECS. To date, no studies to our knowledge have examined sleep in postpartum PTSD.

Maternal PTSD and infant physiological stress responses

Maternal PTSD and its associated dysfunction of the HPA axis can also impact on the stress regulation of the offspring(54-63), such as the infant's HPA secretion patterns(64-66). A growing body of neuroendocrine research supports the notion that an altered maternal HPA axis functioning plays a role in the intergenerational transmission of stress-related psychopathology from parents(67, 68). Overall, findings suggest that PTSD symptoms and cortisol levels in mothers are important to assess, prevent and/or treat as they may affect the relationship with the infant(69-72) and impact the child's later regulative abilities(54). Some authors have suggested low maternal cortisol as a possible mechanism contributing to the mother's difficulty in sensitively attuning to her infant's cues, which in turn

impacts on the infant's reactivity to and recovery from a stressor(73-78).

In contrast, studies assessing the role of ANS in the intergenerational transmission of stress in the postpartum period are so far scarce. Lifetime maternal psychopathology and maternal postnatal psychopathology have been found to be related with reduced HRV of their infants(79). Furthermore, mothers with anxiety symptoms during pregnancy and their infants showed lower HRV(80) and there was a higher sympathetic activation in children of mothers with abuse histories(81). However, to our knowledge none of the previous research has investigated the autonomic functioning in offspring of mothers with PTSD.

Developing an early intervention inspired by behavioural and cognitive neuroscience

To date, there is a lack of evidence-based early interventions for women following a traumatic childbirth(82). At the heart of PTSD are intrusive memories of the traumatic event, in which the person re-experiences aspects of the traumatic event, inflicting significant distress(2). They have also been indicated as a precursor to the disorder(83). Intrusive memories of trauma comprise sensory-perceptual images that are proposed to occur due to excessive perceptual (sensory) processing during a trauma(84).

The way in which individuals process a traumatic event influences their later intrusive memories of the trauma. Evidence from lab-based experiments have demonstrated that a brief behavioural intervention including a reminder cue, mental rotation and a visuospatial task (Tetris) can significantly reduce the frequency of intrusive images following exposure to traumatic film material(85, 86). One study showed that individuals who were instructed to engage in conceptually-driven processing, relative to those engaged in sensory-based, data-driven processing, reported more intrusive memories to a traumatic film(87). It has been hypothesised that tasks which interfere with data-driven processing, such as sensory-perceptual, visuospatial tasks, may reduce the occurrence of intrusive memories of an index event(85, 86). Visuospatial cognitive tasks, such as the computer game Tetris, are thought to compete for resources with visuospatial images(88). Studies of memory consolidation have shown that human memories are likely to still be malleable within 10 min to 6 hours, at which point the memory is thought to stabilise consolidation, making it more resistant to interference from a competing memory(89-91). This indicates that such a working memory task may be most beneficial if delivered within approximately the first 6 hours following a traumatic event (see(92) for a review).

Two recent translational studies presented preliminary evidence for the efficacy of a brief intervention (including Tetris) in reducing the number of traumatic intrusive memories (over 1 week post-trauma) in patients arriving at an accident and emergency department (vs. attention placebo)(93) or in women in the first hours following ECS, the latter when compared with a treatment-as-usual control group(4). In the latter study, per protocol analyses also showed significantly lower re-experiencing symptoms at 1 week and lower rates of PTSD diagnosis at 1 month following ECS (secondary outcomes)(4).

Aims of the present study

The objectives of the present study are to investigate the effects of an early brief, behavioural intervention (including the computer game Tetris) delivered in the hospital context within 6 hours of the trauma, on maternal

mental health and infant development after a traumatic event (ECS). The primary outcome measure will be the presence and the severity of maternal PTSD symptoms at 6 weeks. Secondary objectives will be to measure the impact of this intervention on intrusive memories of the trauma, on stress exposure and perception, on other indicators of maternal psychological vulnerability (including acute stress disorder (ASD), PTSD, anxiety, depression, and sleep), on physiological stress reactivity, on physiological regulation, on mother-infant interactions, and on infant development. The START study also aims to investigate additional maternal and partner psychological vulnerability, partner physiological regulation, partner-infant bonding, and measures related to the acceptability and expectancy of the intervention.

METHODS

Study Design

We will conduct a multi-centre double-blind randomised controlled trial (RCT) with minimal risk testing the effect of an early brief behavioural intervention including computer game play for women at risk of PTSD in the hospital soon following an ECS and their infant, compared with an attention-placebo control task.

Study population, recruitment, group allocation, and blinding

All women who have an ECS ≥34 weeks gestation, give birth to a live baby, and give written consent are eligible to participate. In addition, they have to answer with a score of ≥2 separately for at least two out of four screening questions regarding perceived threat(94). All screening questions are answered on a 7-point Likert scale (*1 = not at all, 7 = extremely*): Did you think that your life was in danger? Did you think that your baby's life was in danger? Did you feel frightened during the birth? Did you feel helpless during the birth?

Exclusion criteria include: established intellectual disability or psychotic illness, insufficient French-speaking level to participate in assessments, severe illness of mother or infant (e.g., cancer, cardiovascular disease, severe neurodevelopmental difficulties, malformations) or if the infant requires intensive care, and alcohol abuse and/or illegal drug use during pregnancy.

Following an ECS and once the mother has sufficiently recovered, the mother's midwife/nurse will assess eligibility and if eligible, will inform the mother about the study. After providing written and informed consent to be screened, participants will be screened immediately for perceived threat of the mother and/or child with four screening questions. If participants score ≥2 separately for at least two out of the four questions, they will be randomly assigned to either the intervention or attention-placebo control group. We aim to recruit 144 women and their infants (see sample size calculation).

If the woman agrees, then the partner will also be informed about the study. Inclusion criteria for the partners are that they were present at the childbirth and give written consent. Partners are excluded if they do not speak French sufficiently well to participate in assessments. All participants will be reimbursed for their time and effort.

The allocation ratio of randomisation is 1:1. The randomization sequence will be generated using a computer-generated block randomisation (StataCorp. 2017. *Stata Statistical Software: Release 15*. College Station, TX) using blocks of sizes 2, 4 and 6 over 144 participants per stratum (stratified by research centre). Opaque envelopes will

be prepared in advance, numbered sequentially by alternating between stratums by block. After conducting the baseline assessment, the clinical midwife/nurse will open the envelope and announce the cognitive task to be carried out (i.e., the cognitive visuospatial task or the attention-placebo control task) to the participant(95). All members of the research group as well as participants are blind to group allocation. All participant data will be coded to ensure confidentiality. After completing the 15-minute cognitive tasks, both women of the control and intervention group will complete the same assessments, as shown in Table 1; see Figure 1 for an overview of the study variables.

Intervention group

Mothers in the intervention group will be instructed to engage in a cognitive visuospatial task, the computer game Tetris, for 15 minutes continuously, on a handheld gaming device (Nintendo DS) (see(4)). They are given a 3-min training in how to play the game and how to actively use mental rotation as they play the game. The intervention is delivered in the same context as that in which the trauma occurred (e.g,, wake-up room) so additional memory reminder cue to the trauma is not used.

The intervention will take place within the first six hours after ECS whilst participants are still in their hospital bed. Procedures are managed not to interfere with important routine care procedures. An unblinded independent researcher will check during the days following the intervention that the intervention protocol was followed correctly via a 4-item survey completed by the participant. Study information and materials refer to 'simple tasks' in both conditions for credibility.

Attention-placebo control group

Mothers assigned to the control group will be asked to engage in a written activity log for 15 minutes (based on previous research(93)). They are instructed to write down very briefly nature and duration of the activities (e.g., "*being with baby for 10 min*", "*phone call for 5 min*") and they are instructed not to sleep. The activity log was selected to control for nonspecific confounding factors, while minimizing the potential for harmful effects, as to date, no preventive treatment in the immediate aftermath of trauma exists that could be used as a control condition(96-99). This control condition was matched with the intervention condition for nonspecific factors including length of the task, contact with the midwife/nurse, location of treatment procedure and engagement in a structured task(93). The attention-placebo control task will take place within the six hours after ECS, whilst participants are still in their hospital bed and will not interfere with important routine care procedures. An unblinded independent researcher will check during the days following childbirth that the attention-placebo control task protocol was followed correctly via a 2-item survey completed by the participant. Study information and materials refer to 'simple tasks' in both conditions for credibility.

Primary outcome

The primary outcomes are differences in the presence and severity of maternal PTSD symptoms between the intervention and the attention-placebo control group at 6 weeks postpartum measured with the Clinician-administered PTSD Scale(100) and the PTSD Checklist(101).

Secondary outcomes

The following outcomes will be assessed via validated assessments at different time-points (i.e., ≥6 hours following ECS, ≤1 and 6 weeks, and 6 months follow-up).

Maternal outcomes

The maternal mental health outcomes will be compared between the two groups at all time-points, including number of intrusive memories of the index trauma (at ≤1 week follow-up) and indicators of maternal psychological vulnerability namely: symptoms of ASD, PTSD, anxiety, depression, sleep and physical activity (at ≥6 hours following ECS, ≤1 and 6 weeks, and 6 months follow-up) (see Table 1). Additional physiological outcomes will be collected in reactivity to stress and as regulation indicators (at 6 weeks and 6 months follow-up). Finally, maternal bonding and sensitivity in mother-infant interaction will also be measured (at ≤1 and 6 weeks, and 6 months follow-up).

Child outcomes

As shown in Table 1, infant development will be assessed at 6 months postpartum. Additionally, physiological outcomes will be assessed in response to stress and as regulation indicators (at 6 weeks and 6 months follow-up).

Other outcomes

Additional measures of maternal and partner psychological vulnerability (at ≤1 and 6 weeks, and 6 months follow-up), partner infant interaction (at ≤1 and 6 weeks, and 6 months follow-up), infant neurodevelopmental vulnerability (at ≤1 week), medical outcomes (at ≤1 and 6 weeks, and 6 months follow-up), and measures related to the acceptability and expectancy of the intervention (at ≥6 hours following ECS) are described in Table 2.

Data collection and visits

Figure 2 summarises study procedures and Table 1 indicates the measures collected at each time point.

Measures

Measures of the primary and secondary outcomes can be found below, measures relating to the 'other outcomes' in the study can be found in Table 2. The time points of when all measures are taken can be seen in Table 1.

Psychological Vulnerability

Clinician-administered PTSD Scale (CAPS-5)(100). The CAPS-5 assesses presence and severity of PTSD symptoms and diagnosis. This gold standard instrument contains 20 items referring to the four symptom clusters, as well as 10 items referring to symptoms duration, distress or impairment, global ratings, and dissociative subtype. Each diagnostic criterion is rated from *0=absent* to *4=extreme/incapacity* in function of symptoms intensity and frequency with a diagnostic cut-off equal to 2. The CAPS-5 has demonstrated good psychometric proprieties(100). In the absence of a French version at the time when the study was designed, a forward-back method was executed to realise a translation and cultural adaptation(102).

The PTSD Checklist (PCL-5)(101). This 20-item self-report questionnaire measures symptoms of PTSD over the past month and is used to assess frequency of PTSD symptoms. The PCL-5 refers to the four symptoms clusters of PTSD and scales on a 5-point scale with *0=not at all* and *4=extremely*. Scores are summed to create a total symptom severity score (103). The French version of the PCL-5 demonstrated strong reliability and validity(104).

Trauma-related intrusive memories diary(4). Intrusive memories of birth-related trauma experienced during the seven days following ECS are reported in a daily diary, adapted from previous work(4), to assess the frequency of intrusive memories of the trauma . For each intrusion, the time, content and type (intrusive memory, nightmare or other) are recorded, as well as the level of distress on a 5-point scale with ratings of *0=not at all* to *5=extremely.*

Acute Stress Disorder Scale (ASDS)(105). This self-assessment instrument measures frequency of ASD symptoms over the last week and is based on DSM 5(106). Each of the 19 items is scored using a scale from *1=not at all* to *5=extremely*, with a higher score indicating higher ASD symptoms. Good sensitivity and specificity has been reported(105). The forward-back method was executed to realise a French version translation and cultural adaptation(102).

Anxiety subscale of Hospital Anxiety and Depression Scale (HADS)(107). This self-report questionnaire measures severity of anxiety symptoms during the last week. The anxiety subscale consists of 7 items scored on a 4-point scale (*0=never*, *3=most of the time*). Higher scores indicate higher distress. Good psychometric properties have been reported for the French version(108).

Edinburgh Postnatal Depression Scale (EPDS)(109). This self-assessment examines postnatal depression symptoms over the previous week(109). The 10 items are scored on a 4-point scale and scores range from 0 to 30. Higher scores indicate higher distress. The French version has demonstrated good psychometric proprieties(110). A clinical cut-off score of 10.5 has been reported for the use of the French validated version(110).

Physical and sleep activity. Frequency and duration of maternal sleep and physical activity of the 5 days following childbirth is measured using an accelerometer watch GENEActiv®(111).

Sleep diary. Mothers record their hours of sleep during the week following ECS in a daily sleep diary.

Pittsburgh Sleep Quality Index (PSQI)(112). This 19-item questionnaire measuring sleep during the past month is composed of seven sleep quality-related subscales. The overall score assessing sleep quality is scored by summing the subscales; scores range from 0 to 21. Higher results indicate poor sleep quality while a score of >5 distinguishes good and poor sleepers. The validated French version of the PSQI has shown good psychometrics proprieties(113).

We also included the 10 items of the PSQI-A(114) to assess PTSD-specific sleep disturbances over the past month, answered on a four-point Likert scale (0=*not during the past month*; 3=*three or more times a week*), that assess the frequency of different kinds of trauma-related sleep disturbance. The items are summed to create the total score, where the higher the score the more disturbed the sleep. The validated French version of the PSQI-A has shown good psychometrics(114).

Maternal and infant physiological stress responses.

Physiological regulation. Resting heart rate of the mother and infant are assessed using resting HRV measured by Firstbeat Bodyguard 2 devices providing a continuous measure of cardiac activity. Resting heart rate will be assessed during the 15 minutes resting period before the stress paradigms (see *Physiological stress reactivity* for stress paradigms) at ≤1 week and 6 months. Baseline salivary cortisol and cortisol daily profile will be established for the mother in the two days after leaving the maternity ward (usually the 6th and 7th day postpartum) and for her and her baby for two days at 6 months through salivary sample; 5 saliva samples are taken per day, including CAR. Maternal salivary cortisol will be collected using Salivettes© Sarstedt (item number: 51.1534.500) and SalivaBio Infant's Swab (Salimetrics, item number: 5001.08 50) for infants.

Physiological stress reactivity. Maternal and infant stress reactivity will be assessed via salivary cortisol and HRV using Firstbeat Bodyguard 2 devices during the stress phases of their respective stress paradigms at 6 months for the mother and at ≤1 week and at 6 months for the infant. The stress paradigm for the mothers is the Trier Social Stress Test (TSST)(115) at 6 months. Maternal salivary cortisol will be measured 7 times before, during, and after the stress paradigms and heart rate throughout the stress paradigm. Stress paradigms for the infants involve the Neonatal Behavioural Assessment Scale (NBAS)(116) at ≤1 week and the double-exposure Face-to-Face Still-Face paradigm (FFSF)(117-120) at 6 months. Salivary cortisol will be measured 3 times, once before and twice after the stressor, and HRV will be measured throughout the stress paradigms. Maternal cortisol will also be collected during the FFSF. Maternal salivary cortisol will be collected using Salivettes© Sarstedt and SalivaBio Infant's Swab (Salimetrics) for infants. Participation in maternal stress reactivity assessments at ≤1 week is optional (involving an additional consent obtained before hospital discharge).

Mother-infant interaction

Mother-to-Infant Bonding Scale (MIBS)(121). This 8-item questionnaire assesses the mothers' feelings towards her new baby in the first few weeks after birth. Eight adjectives are rated on a scale from 0=very much to 5=not at all. Scores are summed to create a total score, with a higher score indicating worse mother-to infant bonding. The MIBS has shown good initial psychometrics(121), and has been validated in French(122).

Emotional Availability Scale (EAS)(123, 124). Maternal sensitivity and responsiveness will be investigated during a free-play session of mothers with their six-months old. Interactions are coded on six dimensions: sensitivity, structuration, intrusion, hostility toward the infant, reactivity to the mother, and maternal involvement(123, 124). Higher scores on each scale indicate better performance. Two trained psychologists blind to the condition will rate each interaction and inter-observer reliability will be calculated. The EAS shows good psychometric properties(123, 124).

Infant developmental outcomes.

Infant Behaviour Questionnaire – Revised (IBQ-R) Very Short Form(125). This is a parent-report questionnaire consisting of 36 items answered on a 7-point Likert-scale (1=never to 7=always). The items assess the frequency of infants' behaviours during the previous two weeks to measure child temperament. The very short form has shown

good psychometric properties(125). There was no available validation French translation. Therefore, the forward-back method was completed to realise a French version translation and cultural adaptation(102)

Bayley Scales of Infant Development (Bayley-III)(126). The cognitive, language and motor subscales of the Bayley Scales of Infant Development assess the developmental functioning of the infant. The scales are administered by a trained psychologist or paediatrician through a standard set of play tasks following a standardized protocol. The composite scores for the subscales are age-standardized with a mean score of 100(127).

Sociodemographic, obstetric and neonatal characteristics

Mothers will report demographic information, including marital status, nationality, profession, level of education(128), and previous and current psychiatric disease as well as any trauma history via a self-report questionnaire. Mothers will also report their height, weight (before pregnancy and current), menstrual cycle, smoking behaviours, and alcohol/drug use. Obstetric data will be extracted from the hospital medical record, such as pregnancy-, labour- and birth-related information, gravidity, parity, mode of previous childbirths, history of miscarriage, stillbirth, and prematurity, pain, medication, birth control, sexual activity, and psychological support. Neonatal characteristics will be collected from the medical record on severity of morbidity (gestational age and weight at birth, Apgar score, neonatal complications), as well as the Clinical Risk Index for Babies (CRIB II)(129), which represents neonatal morbidity severity.

Sample size calculation

Based on a previous proof-of-principle RCT(4), a sample size of n=120 participants is necessary to have 80% power (α=0.05) to detect a between-group difference of d=0.30 of the primary outcome (PTSD symptoms at 6 weeks). Furthermore, we calculated the sample sizes necessary to obtain significant group differences with 80% power (α=0.05) based on small effect sizes (d<0.30) for maternal secondary outcomes (PTSD diagnosis, ASD symptoms and physiological stress reactivity) and infant secondary outcomes (physiological stress reactivity) based on small effect sizes (d<0.30) with 80% power (α=0.05), which range between a total of n=56 and n=84. Predicting a 20% drop-out rate, we aim to recruit 144 women.

PATIENT AND PUBLIC INVOLVEMENT

The acceptability of the intervention was assessed by participants during the previous proof-of-principle RCT(4). A questionnaire of satisfaction and acceptability examined the burden of the intervention. An individual feedback and debriefing session will be offered to each participant. Results will be disseminated in written form to the participants and distributed to the public via social media and public events. They will also be discussed with clinical professionals involved in this project.

DATA MANAGEMENT AND STATISTICAL ANALYSES

All study data will be entered by research staff. Study data will be managed using REDCap electronic data capture tools hosted at Lausanne University Hospital(130, 131). REDCap (Research Electronic Data Capture) is a secure, web-based software platform designed to support data capture for research studies. Double data entry will be done for the primary outcomes. For the rest of the data, a random 5% will be double-checked. Access to the full final trial

dataset will be restricted to the principal investigator.

For the primary analyses, group differences regarding the mean subscale and total scores of the PCL-5 and CAPS-5 at 6 weeks will be analysed using separate linear regression analyses. Analyses will be adjusted for recruitment centre and the respective baseline values. Associations between primary outcomes and potential confounders, such as maternal and gestational age, will first be assessed applying univariate tests. Subsequent analyses will be adjusted for significant covariates. For secondary aims, the analyses will be performed for differences in changes between groups and differences between groups at different time points in maternal and infant outcomes. Proportion of participants meeting the diagnostic criteria for PTSD at 6 weeks and 6 months between the two groups will also be compared using logistic regression analyses. The same procedure for identifying significant covariates described above will be applied here. Furthermore, post-hoc exploratory analyses will be conducted but described as such in publications. All regression analyses regarding cortisol data will be adjusted for potential covariates, such as co-sleeping, breastfeeding, menstrual cycle, and infant and maternal medication. For HRV analyses interbeat intervals (IBIs) from baseline, stress task and recovery will be analysed by the extraction from ECG recordings. Statistical parameters of HRV(132) will be calculated using Kubios HRV Analysis2.2 software(133). Time domain measures and spectral frequency measures will be used for calculations. Multiple imputation methods will be used to manage missing data, if appropriate.

ETHICAL APPROVAL

This study protocol was approved by the Human Research Ethics Committee of the Canton de Vaud (Switzerland, study number 2017-02142, protocol version 5 of September 13rd 2019) and is registered in *clinicaltrials.gov* (NCT03576586). Substantial amendments will only be implemented after approval of the ethics committee, and all non-substantial amendments are communicated to the ethics committee within the Annual Safety Report. Participating mothers and, where included, partners will provide their written informed consent before their enrolment in the study by the clinical and research staff. The written informed consent contains an optional part on the re-use of data in ancillary studies. Participation will not interfere with typical care provided to patients after an ECS. The scientific conduct of the study is overseen by an interdisciplinary steering committee of national and international experts. Confidentiality will be ensured by utilising subject identification code numbers to correspond to treatment data in the computer files.

ACKNOWLEDGMENTS

We thank Pierluigi Ballabeni for his statistical advice and the generation of the randomization sequence. We also thank our interns for help with study co-ordination and data collection: Lara Schütz, Anna Favero, Yasmina Lotfi, Mathilde Duroux, Cassie Pernet, Daniela Barros Rodrigues, Mélanie Hausser, and Annabelle Reuse. For institutional support, access to the study population, help with recruitment, data collection, and administrative support, we acknowledge Laetitia Accrombessi, Danièle Losguardi, Pascale Gerdy, Maria-Teresa Adjaho, Lauretta Monney, Nadia Carota, Annette Schauenberg, Laetitia Favre, Antonina Chilin, Céline Favrod, and all clinical teams of the labor and postpartum wards at the Lausanne and Geneva University Hospitals.

COLLABORATORS

The following are members of the *START Research Consortium* (including the authors of the present article), listed in alphabetical order:

- Valérie Avignon (Woman-Mother-Child Department, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland; valerie.avignon@chuv.ch),
- Susan Ayers (Centre for Maternal and Child Health Research, School of Health Sciences, City, University of London, London, UK; susan.ayers.1@city.ac.uk),
- Myriam Bickle-Graz (Neonatology Service, Woman-Mother-Child Department, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland; myriam.bickle-graz@chuv.ch),
- Cristina Borradori Tolsa (Department of Pediatrics, Geneva University Hospitals, Geneva, Switzerland; cristina.borradoritolsa@hcuge.ch),
- Julie Bourdin (Woman-Mother-Child Department, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland; julie.bourdin@chuv.ch),
- Camille Deforges (Institute of Higher Education and Research in Healthcare (IUFRS), University of Lausanne, Lausanne, Switzerland; camille.deforges@chuv.ch),
- Dominique Delecraz (Department of Woman, Child and Adolescent, Geneva University Hospitals, Geneva, Switzerland; dominique.delecraz@hcuge.ch),
- David Desseauve (Woman-Mother-Child Department, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland; david.desseauve@chuv.ch),
- Ulrike Ehlert (Department of Clinical Psychology and Psychotherapy, University of Zurich, Zurich, Switzerland; u.ehlert@psychologie.uzh.ch),
- Manuella Epiney (Department of Woman, Child and Adolescent, Geneva University Hospitals, Geneva, Switzerland; manuella.epiney@hcuge.ch),
- Isabelle Eragne (Department of Woman, Child and Adolescent, Geneva University Hospitals, Geneva, Switzerland; Isabelle.Eragne@hcuge.ch),
- Emily A. Holmes (Department of Psychology, Uppsala University, Uppsala, Sweden; emily.holmes@psyk.uu.se),
- Antje Horsch (Institute of Higher Education and Research in Healthcare (IUFRS), University of Lausanne and Neonatology Service, Woman-Mother-Child Department, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland; antje.horsch@chuv.ch),
- Justine Imbert (Woman-Mother-Child Department, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland; justine.imbert@chuv.ch),
- Nadine Messerli-Bürgy (Clinical Child Psychology & Biological Psychology, University of Fribourg, Fribourg, Switzerland; nadine.messerli@unifr.ch),
- Micah M. Murray (Faculty of Biology and Medicine, University of Lausanne, Lausanne, Switzerland; Micah.Murray@chuv.ch),

- Mathilde Morisod Harari (Service of Child and Adolescent Psychiatry, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland; mathilde.morisod@chuv.ch),
- Kate Porcheret (Turner Institute for Brain and Mental Health, Monash University, Monash University, Melbourne, Australia; kate.porcheret@monash.edu),
- Jardena J. Puder (Woman-Mother-Child Department, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland; jardena.puder@chuv.ch),
- Véronique Othenin-Girard (Department of Woman, Child and Adolescent, Geneva University Hospitals, Geneva, Switzerland; veronique.othenin-girard@hcuge.ch),
- Suzannah Stuijfzand (Institute of Higher Education and Research in Healthcare (IUFRS), University of Lausanne, Lausanne, Switzerland; suzannah.ravenscroft@chuv.ch),
- Vania Sandoz, M.Sc. (Institute of Higher Education and Research in Healthcare (IUFRS), University of Lausanne, Lausanne, Switzerland; vania.sandoz@chuv.ch),
- Daniel S. Schechter (Service of Child and Adolescent Psychiatry, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland, and Department of Psychiatry, University of Geneva Faculty of Medicine, Geneva, daniel.schechter@hcuge.ch),
- Nicole Sekarski (Paediatric Cardiology Unit, Woman-Mother-Child Department, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland; nicole.sekarski@chuv.ch),
- Jean-François Tolsa (Department of Woman-Mother-Child, Clinic of Neonatology, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland; jean-francois.tolsa@chuv.ch),
- Yvan Vial (Obstetrics and Gynecology Service, Woman-Mother-Child Department, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland; yvan.vial@chuv.ch).

AUTHOR CONTRIBUTIONS

AH designed the study with input from all co-authors and members of the consortium. VS, ME, YV, NS, NMB, UE, MBG, MMH, KP, DS, SA and EH participated in the design of the study. AH, VS, CD and SS drafted the manuscript. VS, CD, ME, NMB, MBG, SS, EH and AH significantly contributed to the establishment and refinement of study procedures. All authors critically revised the manuscript and approved the final version of the manuscript.

FUNDING

The START study is funded by a project grant from the Swiss National Science Foundation (SNF 32003B_172982/1).

COMPETING INTERESTS

None declared.

ETHICAL APPROVAL

Ethical approval was granted by the Human Research Ethics Committee of the Canton de Vaud (study number 2017-02142).

REFERENCES

1. Soet JE, Brack GA, Dilorio C. Prevalence and predictors of women's experience of psychological trauma during childbirth. Birth. 2003;30(1):36-46.
2. American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 5 ed. Arlington, VA: American Psychiatric Publishing; 2013.
3. Dikmen-Yildiz P, Ayers S, Phillips L. The prevalence of posttraumatic stress disorder in pregnancy and after birth: a systematic review and meta-analysis. Journal of affective disorders. 2017;208:634-47.
4. Horsch A, Vial Y, Favrod C, Morisod Harari M, Blackwell SE, Watson P, et al. Reducing intrusive traumatic memories after emergency caesarean section: a proof-of-principle randomized controlled study. Behaviour research and therapy. 2017;94:36-47.
5. Rogal SS, Poschman K, Belanger K, Howell HB, Smith MV, Medina J, et al. Effects of posttraumatic stress disorder on pregnancy outcomes. Journal of affective disorders. 2007;102(1-3):137-43.
6. Seng JS, Oakley DJ, Sampselle CM, Killion C, Graham-Bermann S, Liberzon I. Posttraumatic stress disorder and pregnancy complications. Obstetrics & Gynecology. 2001;97(1):17-22.
7. Cook N, Ayers S, Horsch A. Maternal posttraumatic stress disorder during the perinatal period and child outcomes: a systematic review. Journal of affective disorders. 2018;225:18-31.
8. Hofberg K, Brockington I. Tokophobia: an unreasoning dread of childbirth. The British journal of psychiatry : the journal of mental science. 2000;176(1):83-5.
9. Morland L, Goebert D, Onoye J, Frattarelli L, Derauf C, Herbst M, et al. Posttraumatic stress disorder and pregnancy health: preliminary update and implications. Psychosomatics. 2007;48(4):304-8.
10. Garthus-Niegel S, Horsch A, Ayers S, Junge-Hoffmeister J, Weidner K, Eberhard-Gran M. The influence of postpartum PTSD on breastfeeding: a longitudinal population-based study. Birth. 2018;45(2):193-201.
11. Garthus-Niegel S, Horsch A, Bickle Graz M, Martini J, von Soest T, Weidner K, et al. The prospective relationship between postpartum PTSD and child sleep: A 2-year follow-up study. Journal of affective disorders. 2018;241:71-9.
12. Garthus-Niegel S, Horsch A, Handtke E, von Soest T, Ayers S, Weidner K, et al. The impact of postpartum posttraumatic stress and depression symptoms on couples' relationship satisfaction: a population-based prospective study. Frontiers in Psychology. 2018;9:1728.

13. Pisoni C, Spairani S, Fauci F, Ariaudo G, Tzialla C, Tinelli C, et al. Effect of maternal psychopathology on neurodevelopmental outcome and quality of the dyadic relationship in preterm infants: an explorative study. The Journal of Maternal-Fetal & Neonatal Medicine. 2018:1-10.

14. Grace SL, Evindar A, Stewart D. The effect of postpartum depression on child cognitive development and behavior: a review and critical analysis of the literature. Archives of Women's Mental Health. 2003;6(4):263-74.

15. Pearson RM, Bornstein MH, Cordero M, Scerif G, Mahedy L, Evans J, et al. Maternal perinatal mental health and offspring academic achievement at age 16: the mediating role of childhood executive function. Journal of Child Psychology and Psychiatry. 2016;57(4):491-501.

16. Sandoz V, Bickle-Graz M, Camos V, Horsch A. Maternal postpartum depression symptoms are negatively associated with emotion regulation of children born very preterm. Acta paediatrica. 2019;108(5):969-70.

17. Bauer A, Parsonage M, Knapp M, Iemmi V, Adelaja B. The costs of perinatal mental health problems. London: Centre for Mental Health and London School of Economics; 2014.

18. Berger A, Bachmann N, Signorell A, Erdin R, Oelhafen S, Reich O, et al. Perinatal mental disorders in Switzerland: prevalence estimates and use of mental-health services. Swiss Medical Weekly. 2017;147(0910):w14417.

19. Horsch A. Post traumatic stress disorder following childbirth and pregnancy loss. In: Beinard H, Kennedy P, S. L, editors. Clinical Psychology in Practice. Oxford: Blackwell, BPS; 2009. p. 274-87.

20. Bradley R, Slade P. A review of mental health problems in fathers following the birth of a child. Journal of reproductive and infant psychology. 2011;29(1):19-42.

21. Bradley R, Slade P, Leviston A. Low rates of PTSD in men attending childbirth: a preliminary study. British Journal of Clinical Psychology. 2008;47(3):295-302.

22. Lane A, Keville R, Morris M, Kinsella A, Turner M, Barry S. Postnatal depression and elation among mothers and their partners: prevalence and predictors. British Journal of Psychiatry. 1997;171(6):550-5.

23. Horsch A, Jacobs I, Gilbert L, Favrod C, Schneider J, Morisod Harari M, et al. Impact of perinatal asphyxia on parental mental health and bonding with the infant: a questionnaire survey of Swiss parents. BMJ Paediatrics Open. 2017;1(1):e000059.

24. Ayers S, Wright DB, Wells N. Symptoms of post-traumatic stress disorder in couples after birth: association with the couple's relationship and parent–baby bond. Journal of Reproductive and Infant Psychology. 2007;25(1):40-50.

25. Lamb ME. The role of the father in child development. 4th ed. Sons JW, editor. Hoboken, N.J.: John Wiley & Sons; 2004.

26. Paulson JF, Keefe HA, Leiferman JA. Early parental depression and child language development. Journal of Child Psychology and Psychiatry. 2009;50(3):254-62.

27. Ramchandani P, Psychogiou L. Paternal psychiatric disorders and children's psychosocial development. The Lancet. 2009;374(9690):646-53.

28. de Kloet ER, Joels M, Holsboer F. Stress and the brain: from adaptation to disease. Nature reviews Neuroscience. 2005;6(6):463-75.

29. Rohleder N, Nater UM, Wolf JM, Ehlert U, Kirschbaum C. Psychosocial stress-induced activation if salivary alpha-amylase. An indicator of sympathetic activity? Annals of the New York Academy of Sciences. 2004;1032(1):258-63.

30. Nater UM, Rohleder N, Scholtz W, Ehlert U, Kirschbaum C. Determinants of the diurnal course of salivary alpha-amylase. Psychoneuroendocrinology. 2007;32(4):392-401.

31. Ehlert U, Gaab J, Heinrichs M. Psychoneuroendocrinological contributions to the etiology of depression, posttraumatic stress disorder, and stress-related bodily disorders: the role of the hypothalamus–pituitary–adrenal axis. Biological psychology. 2001;57:141-52.

32. De Kloet ER, Vermetten E, Heijnen CJ, Geuze E, Lenjes EGWM, Westenberg HGM. Enhanced cortisol suppression in response to dexamethasone administration in traumatized veterans with and without posttraumatic stress disorder. Psychoneuroendocrinology. 2007;32(3):215-26.

33. Neylan TC, Brunet A, Pole N, Best SR, Metzler TJ, Yehuda R. PTSD symptoms predict waking salivary cortisol levels in police officers. Psychoneuroendocrinology. 2005;30(4):373-81.

34. Wessa M, Rohleder N, Kirschbaum C, Flor H. Altered cortisol awakening response in posttraumatic stress disorder. Psychoneuroendocrinology. 2006;31(2):209-15.

35. Yehuda R, Golier JA, Kaufman S. Circadian rhythm of salivary cortisol in Holocaust survivors with and without PTSD. American Journal of Psychiatry. 2005;162(5):998-1000.

36. Pinto RJ, Correia-Santos P, Costa-Leite J, Levendosky AA, Jongenelen I. Cortisol awakening response among women exposed to intimate partner violence. Psychoneuroendocrinology. 2016;74:57-64.

37. Young EA, Breslau N. Cortisol and catecholamines in posttraumatic stress disorder: an epidemiologic community study. Archives of General Psychiatry. 2004;61(4):394-401.

38. Shalev AY, Videlock EJ, Peleg T, Segman R, Pitman RK, Yehuda R. Stress hormones and posttraumatic stress disorder in civilian trauma victims: a longitudinal study. Part I: HPA axis responses. The International Journal of Neuropsychopharmacology. 2008;11(3):365-72.

39. Meewisse ML, Reitsma JB, De Vries G-J, Gersons BPR, Olff M. Cortisol and post-traumatic stress disorder in adults. British Journal of Psychiatry. 2007;191(5):387-92.

40. Habersaat S, Borghini A, Nessi J, Pierrehumbert B, Forcada-Guex M, Ansermet F, et al. Posttraumatic stress symptoms and cortisol regulation in mothers of very preterm infants. Stress and Health. 2014;30(2):134-41.

41. Santa Ana EJ, Saladin ME, Back SE, Waldrop AE, Spratt EG, McRae AL, et al. PTSD and the HPA axis: Differences in response to the cold pressor task among individual with child vs. adult trauma. Psychoneuroendocrinology. 2006;31(4):501-9.

42. Bremner JD, Vythilingam M, Vermetten E, Adil J, Khan S, Nazeer A, et al. Cortisol response to a cognitive stress challenge in posttraumatic stress disorder (PTSD) related to childhood abuse. Psychoneuroendocrinology. 2003;28(6):733-50.

43. Vyas A, Bernal S, Chattarji S. Effects of chronic stress on dendritic arborization in the central and extended amygdala. Brain Research. 2003;965(1-2):290-4.

44. Fries E, Hesse J, Hellhammer J, Hellhammer DH. A new view on hypocortisolism. Psychoneuroendocrinology. 2005;30(10):1010-6.

45. Chrousos GP. Stress and disorders of the stress system. Nature reviews endocrinology. 2009;5(7):374-81.

46. Beauchaine TP, Thayer JF. Heart rate variability as a transdiagnostic biomarker of psychopathology. International Journal of Psychophysiology. 2015;98(2):338-50.

47. Nagpal M, Gleichauf K, Ginsberg J. Meta-analysis of heart rate variability as a psychophysiological indicator of posttraumatic stress disorder. Trauma & Treatment. 2013;3(1):1000182.

48. Norte CE, Souza GG, Vilete L, Marques-Portella C, Coutinho ES, Figueira I, et al. They know their trauma by heart: an assessment of psychophysiological failure to recover in PTSD. Journal of affective disorders. 2013;150(1):136-41.

49. Maher MJ, Rego SA, Asnis GM. Sleep disturbances in patients with post-traumatic stress disorder. CNS Drugs. 2006;20(7):567-90.

50. Porcheret K, Holmes EA, Goodwin GM, Foster RG, Wulff K. Psychological impact of an analogue traumatic event reduced by sleep deprivation. Sleep. 2015;38(7):1017-25.

51. Kleim B, Wysokowsky J, Schmid N, Seifritz E, Rasch B. Effects of sleep after experimental trauma on intrusive emotional memories. Sleep. 2016;39(12):2125-32.

52. Woud ML, Cwik JC, Blackwell SE, Kleim B, Holmes EA, Adolph D, et al. Does napping enhance the effects of Cognitive Bias Modification-Appraisal training? An experimental study. PloS one. 2018;13(2):e0192837.

53. Porcheret K, van Heugten–van der Kloet D, Goodwin GM, Foster RG, Wulff K, Holmes EA. Investigation of the impact of total sleep deprivation at home on the number of intrusive memories to an analogue trauma. Translational psychiatry. 2019;9(1).

54. Feldman R. Parent-Infant synchrony and the construction of shared timing: psychological precursors, developmental outcomes, and risk conditions Journal of Child Psychology and Psychiatry. 2007;48(3/4):329-54.

55. Treyvaud K, Anderson VA, Lee KJ, Woodward LJ, Newnham C, Inder TE, et al. Parental mental health and early social-emotional development of children born very preterm. Journal of pediatric psychology. 2010;35(7):768-77.

56. Blandon AY, Calkins SD, Keane SP, O'Brien M. Individual differences in trajectories of emotion regulation processes: the effects of maternal depressive symptomatology and children's physiological regulation. Developmental Psychology. 2008;44(4):1110-23.

57. Eisenberg N, Valiente C, Morris AS, Fabes R, Cumberland A, Reiser M, et al. Longitudinal relations among parental emotional expressivity, children's regulation, and quality of socio-emotional functioning Developmental Psychology. 2003;39(1):3-19.

58. Feng X, Shaw DS, Kovacs M, Lane T, O'Rourke FE, Alarcon JH. Emotion regulation in preschoolers: the roles of behavioral inhibition, maternal affective behavior, and maternal depression. Journal of Child Psychology and Psychiatry. 2008;49(2):132-41.

59. Francis DD, Meaney MJ. Maternal care and the development of stress responses. Current Opinion in Neurobiology. 1999;9(1):128-34.

60. Liu D, Diorio J, Tannenbaum B, Caldji C, Francis D, Freedman A, et al. Maternal care, hippocampal glucocorticoid receptors, and hypothalamic-pituitary-adrenal responses to stress. Science. 1997;277(5332):1659-62.

61. Gunzenhauser N. Infant stimulation: for whom, what kind, when, and how much? Skillman, NJ: Johnson and Johnson; 1987.

62. Schore AN. Affect regulation and the origin of the self. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc; 1994.

63. Liu K, Ruggero CJ, Goldstein B, Klein DN, Perlman G, Broderick J, et al. Elevated cortisol in healthy female adolescent offspring of mothers with posttraumatic stress disorder. Journal of Anxiety Disorders. 2016;40:37-43.

64. Essex MJ, Klein MH, Cho E, Kalin NH. Maternal stress begining in infancy may sensitize children to later stress exposure : Effects on cortisol and behavior. Biological Psychiatry. 2002;52(8):776 - 84.

65. Lupien SJ, King S, Meaney MJ, McEwen BS. Child's stress hormone levels correlate with mother's socio-economic status and depressive state. Biological Psychiatry. 2000;48(10):976 - 80.

66. Warren SL, Gunnar MR, Kagan J, Anders TF, Simmens SJ, Rones M, et al. Maternal panic disorder: infant temperament, neurophysiology and parentiong behaviors. Journal of the American Academy of Child and Adolescent Psychiatry. 2003;42(7):814 - 25

67. Yehuda R, Halligan SL, Bierer LM. Cortisol levels in adult offspring of Holocaust survivors: relation to PTSD symptom severity in the parent and child. Psychoneuroendocrinology. 2002;27(1-2):171-80.

68. Ehlert U. Understanding the trans-generational consequences of prenatal stress. Journal of psychosomatic research. 2013;75(4):297-8.

69. Muller-Nix C, Forcada-Guex M, Pierrehumbert B, Jaunin L, Borghini A, Ansermet F. Prematurity, maternal stress and mother-child interactions. Early Human Development. 2004;79(2):145-58.

70. Schmücker G, Brisch K-H, Köhntop B, Betzler S, Österle M, Pohlandt F, et al. The influence of prematurity, maternal anxiety, and infants' neurobiological risk on mother - infant interactions. Infant Mental Health Journal. 2005;26(5):423 - 41.

71. Zelkowitz P, Papageorgiou A. Maternal anxiety: an emerging prognostic factor in neonatology. Acta Paediatrica. 2005;94(12):1704 - 5

72. Korja R, Savonlahti E, Ahlqvist-Bjorkroth S, Stolt S, Haataja L, Lapinleimu H, et al. Maternal depression is associated with mother-infant interaction in preterm infants. Acta paediatrica. 2008;97(6):724-30.

73. Crockett EE, Holmes BM, Granger DA, Lyons-Ruth K. Maternal Disrupted Communication During Face-to-Face Interaction at 4 months: Relation to Maternal and Infant Cortisol Among at-Risk Families. Infancy. 2013;18(6):1111-34.

74. Ahnert L, Gunnar MR, Lamb ME, Barthel M. Transition to Child Care: Associations with Infant–Mother Attachment, Infant Negative Emotion, and Cortisol Elevations. Child Development. 2004;75(3):639-50.

75. Domes G, Heinrichs M, Reichwald U, Hautzinger M. Hypothalamic-pituitary-adrenal axis reactivity to psychological stress and memory in middle-aged women: high responders exhibit enhanced declarative memory performance. Psychoneuroendocrinology. 2002;27(7):843 - 53.

76. Nachmias M, Gunnar M, Mangelsdorf S, Parritz RH, Buss K. Behavioral inhibition and stress reactivity: the moderating role of attachment security. Child development. 1996;67(2):508-22.

77. Spangler G, Scheubeck R. Behavioral organization in newborns and its relation to adrenocortical and cardiac activity. Child Development. 1993;64:622-33.

78. Cordero MI, Moser DA, Manini A, Suardi F, Sancho-Rossignol A, Torrisi R, et al. Effects of interpersonal violence-related post-traumatic stress disorder (PTSD) on mother and child diurnal cortisol rhythm and cortisol reactivity to a laboratory stressor involving separation. Hormones and behavior. 2017;90:15-24.

79. Dierckx B, Tulen JH, van den Berg MP, Tharner A, Jaddoe VW, Moll HA, et al. Maternal psychopathology influences infant heart rate variability: Generation R Study. Psychosomatic Medicine. 2009;71(3):313-21.

80. Braeken MA, Kemp AH, Outhred T, Otte RA, Monsieur GJ, Jones A, et al. Pregnant mothers with resolved anxiety disorders and their offspring have reduced heart rate variability: implications for the health of children. PloS one. 2013;8(12):e83186.

81. Jovanovic T, Smith A, Kamkwalala A, Poole J, Samples T, Norrholm SD, et al. Physiological markers of anxiety are increased in children of abused mothers. Journal of Child Psychology and Psychiatry. 2011;52(8):844-52.

82. Bastos MH, Furuta M, Small R, McKenzie-McHarg K, Bick D. Debriefing interventions for the prevention of psychological trauma in women following childbirth. Cochrane Database of Systematic Reviews. 2015;CD007194(4).

83. O'Donnell ML, Elliott P, Lau W, Creamer M. PTSD symptom trajectories: from early to chronic response. Behaviour research and therapy. 2007;45(3):601-6.

84. Brewin CR. Episodic memory, perceptual memory, and their interaction: foundations for a theory of posttraumatic stress disorder. Psychol Bulletin. 2014;140(1):69-97.

85. Holmes EA, James EL, Coode-Bate T, Deeprose C. Can playing the computer game "Tetris" reduce the build-up of flashbacks for trauma? A proposal from cognitive science. PloS one. 2009;4(1):e4153.

86. Holmes EA, James EL, Kilford EJ, Deeprose C. Key steps in developing a cognitive vaccine against traumatic flashbacks: visuospatial Tetris versus verbal Pub Quiz. PloS one. 2010;5(11):e13706.

87. Kindt M, van den Hout M, Arntz A, Drost J. The influence of data-driven versus conceptually-driven processing on the development of PTSD-like symptoms. Journal of behavior therapy and experimental psychiatry. 2008;39(4):546-57.

88. Deeprose C, Zhang S, Dejong H, Dalgleish T, Holmes EA. Imagery in the aftermath of viewing a traumatic film: Using cognitive tasks to modulate the development of involuntary memory. Journal of behavior therapy and experimental psychiatry. 2012;43(2):758-64.

89. Walker MP, Brakefield T, Hobson JA, Stickgold R. Dissociable stages of human memory consolidation and reconsolidation. Nature. 2003;425(6958):616-20.

90. McGaugh JL. Memory--a Century of Consolidation. Science. 2000;287(5451):248-51.

91. Nader K, Schafe GE, LeDoux JE. The labile nature of consolidation theory. Nature Reviews Neuroscience. 2000;1(3):216-9.

92. Iyadurai L, Visser RM, Lau-Zhu A, Porcheret K, Horsch A, Holmes EA, et al. Intrusive memories of trauma: a target for research bridging cognitive science and its clinical application. Clinical psychology review. 2018;69:67-82.

93. Iyadurai L, Blackwell SE, Meiser-Stedman R, Watson PC, Bonsall MB, Geddes JR, et al. Preventing intrusive memories after trauma via a brief intervention involving Tetris computer game play in the emergency department: a proof-of-concept randomized controlled trial. Molecular psychiatry. 2018;23(3):674-82.

94. Foa EB, Cashman L, Jaycox L, Perry K. The validation of a self-report measure of posttraumatic stress disorder: the Posttraumatic Diagnostic Scale. Psychological assessment. 1997;9(4):445-51.

95. Kim J, Shin W. How to Do Random Allocation (Randomization). Clinics in Orthopedic Surgery. 2014;6(1):103-9.

96. Furuta M, Horsch A, Ng ES, Bick D, Spain D, Sin J. Effectiveness of trauma-focused psychological therapies for treating post-traumatic stress disorder symptoms in women following childbirth: a systematic review and meta-analysis. Frontiers in psychiatry. 2018;9.

97. Roberts NP, Kitchiner NJ, Kenardy J, Bisson JI. Multiple session early psychological interventions for the prevention of post-traumatic stress disorder. Cochrane Database of Systematic Reviews. 2009.

98. Sijbrandij M, Kleiboer A, Bisson JI, Barbui C, Cuijpers P. Pharmacological prevention of post-traumatic stress disorder and acute stress disorder: a systematic review and meta-analysis. The Lancet Psychiatry. 2015;2(5):413-21.

99. Rose SC, Bisson J, Churchill R, Wessely S. Psychological debriefing for preventing post traumatic stress disorder (PTSD). Cochrane Database of Systematic Reviews. 2002;2:CD000560.

100. Weathers FW, Bovin MJ, Lee DJ, Sloan DM, Schnurr PP, Kaloupek DG, et al. The Clinician-Administered PTSD Scale for DSM–5 (CAPS-5): development and initial psychometric evaluation in military vgeterans. Psychological Assessment. 2018;30(3):383-95.

101. Blevins CA, Weathers FW, Davis MT, Witte TK, Domino JL. The posttraumatic stress disorder checklist for DSM 5 (PCL 5): Development and initial psychometric evaluation. Journal of Traumatic Stress. 2015;28(6):489-98.

102. Wild D, Grove A, Martin M, Eremenco S, McElroy S, Verjee-Lorenz A, et al. Principles of Good Practice for the Translation and Cultural Adaptation Process for Patient-Reported Outcomes (PRO) Measures: report of the ISPOR Task Force for Translation and Cultural Adaptation. Value Health. 2005;8(2):94-104.

103. Bovin MJ, Marx BP, Weathers FW, Gallagher MW, Rodriguez P, Schnurr PP, et al. Psychometric properties of the PTSD checklist for diagnostic and statistical manual of mental disorders–fifth edition (PCL-5) in veterans. Psychological Assessment. 2016;28(11):1379-91.

104. Ashbaugh AR, Houle-Johnson S, Herbert C, El-Hage W, Brunet A. Psychometric Validation of the English and French Versions of the Posttraumatic Stress Disorder Checklist for DSM-5 (PCL-5). PloS one. 2016;11(10):e0161645.

105. Bryant RA, Moulds ML, Guthrie RM. Acute Stress Disorder Scale: a self-report measure of acute stress disorder. Psychological Assessment. 2000;12(1):61-8.

106. American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 4th ed., text rev. ed. Washington, DC: American Psychiatric Publishing; 2000.

107. Zigmond AS, Snaith RP. The Hospital Anxiety and Depression Scale. Acta psychiatrica scandinavica. 1983;67(6):361-70.

108. Bocerean C, Dupret E. A validation study of the Hospital Anxiety and Depression Scale (HADS) in a large sample of French employees. BMC Psychiatry. 2014;14(1).

109. Cox JL, Holden JM, Sagovsky R. Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. British Journal of Psychiatry. 1987;150(6):782-6.

110. Guedeney N, Fermanian J. Validation study of the French version of the Edinburgh Postnatal Depression Scale (EPDS): new results about use and psychometric properties. Eur Psychiatry. 1998;13(2):83-9.

111. Esliger DW, Rowlands AV, Hurst TL, Catt M, Murray P, Eston RG. Validation of the GENEA Accelerometer. Medicine & Science in Sports & Exercise. 2011;43(6):1085-93.

112. Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. Psychiatry research. 1989;28(2):193-213.

113. Blais F, Gendron L, Mimeault V, Morin C. Evaluation de l'insomnie: Validation de trois questionnaires. L'Encéphale: Revue de psychiatrie clinique biologique et thérapeutique. 1997;23(6):447-53.

114. Ait-Aoudia M, Levy PP, Bui E, Insana S, de Fouchier C, Germain A, et al. Validation of the French version of the Pittsburgh Sleep Quality Index Addendum for posttraumatic stress disorder. European journal of psychotraumatology. 2013;4(1):19298.

115. Kirschbaum C, Pirke K-M, Hellhammer DH. The 'Trier Social Stress Test'–a tool for investigating psychobiological stress responses in a laboratory setting. Neuropsychobiology. 1993;28(1-2):76-81.

116. Brazelton TB, Nugent JK. The Neontal Behavioral Assessment Scale. 4th ed. London: Mac Keith Press; 2011.

117. Tronick E, Als H, Adamson L, Wise S, Brazelton TB. The infant's response to entrapment between contradictory messages in face-to-face interaction. Journal of the American Academy of Child Psychiatry. 1978;17(1):1-13.

118. Provenzi L, Giusti L, Montirosso R. Do infants exhibit significant cortisol reactivity to the Face-to-Face Still-Face paradigm? A narrative review and meta-analysis. Developmental Review. 2016;42:34-55.

119. Haley DW, Stansbury K. Infant stress and parent responsiveness: regulation of physiology and behavior during still-face and reunion. Child development. 2003;74(5):1534-46.

120. DiCorcia JA, Snidman N, Sravish AV, Tronick E. Evaluating the Nature of the Still-Face Effect in the Double Face-to-Face Still-Face Paradigm Using Different Comparison Groups. Infancy. 2016;21(3):332-52.

121. Taylor A, Atkins R, Kumar R, Adams D, Glover V. A new Mother-to-Infant Bonding Scale: links with early maternal mood. Archives of women's mental health. 2005;8(1):45-51.

122. Bienfait M, Haquet A, Maury M, Faillie J, Combes, C., Cambonie G. Traduction française de l'autoquestionnaire MIBS (Mother to Infant Bonding Scale) et validation comme évaluation du lien mère-nouveau-né en maternité. Devenir. 2017;29(4):233-53.

123. Biringen Z. The Emotional Availability (EA) Scales and EA Zones Evaluation: Infancy/early childhood version; middle childhood/youth versions; therapist/interventionist/professional manual; couple relationship manual. 4 ed. Colorado: Boulder; 2008.

124. Biringen Z, Derscheid D, Vliegen N, Closson L, Easterbrooks MA. Emotional Availability (EA): Theoretical background, empirical research using the EA Scales and clinical implications. . Developmental Review. 2014;34:114-67.

125. Putnam SP, Helbig AL, Gartstein MA, Rothbart MK, Leerkes E. Development and Assessment of Short and Very Short Forms of the Infant Behavior Questionnaire–Revised. Journal of Personality Assessment. 2014;96(4):445-58.

126. Bayley N, Reuner G. Bayley scales of infant and toddler development: Bayley-III. San Antonio, Texas, USA: Harcourt Assessment, Psych. Corporation; 2006.

127. Albers EM, Marianne Riksen-Walraven J, Sweep FC, Weerth Cd. Maternal behavior predicts infant cortisol recovery from a mild everyday stressor. Journal of Child Psychology and Psychiatry. 2008;49(1):97-103.

128. Largo RH, Pfister D, Molinari L, Kundu S, Lipp A, Duc G. Significance of prenatal, perinatal and postnatal factors in the development of AGA preterm infants at five to seven years. Developmental Medicine & Child Neurology. 1989;31(4):440-56.

129. Parry G, Tucker J, Tarnow-Mordi W, Group UKNSSC. CRIB II: an update of the clinical risk index for babies score. Lancet. 2003;361(9371):1789-91.

130. Harris PA, Taylor R, Minor BL, Elliott V, Fernandez M, O'Neal L, et al. The REDCap consortium: Building an international community of software platform partners. Journal of Biomedical Informatics. 2019;95:103208.

131. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JGJJobi. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. Journal of Biomedical Informatics. 2009;42(2):377-81.

132. Camm AJ, Malik M, Bigger J, Breithardt G, Cerutti S, Cohen R, et al. Heart rate variability: standards of measurement, physiological interpretation and clinical use. . European Heart Journal. 1996;17(3):354-81.

133. Tarvainen MP, Niskanen JP, Lipponen JA, Ranta-Aho PO, Karjalainen PA. Kubios HRV--heart rate variability analysis software. Computer methods and programs in biomedicine. 2014;113(1):210-20.

134. Razurel C, Kaiser B, Dupuis M, Antonietti J-P, Sellenet C, Epiney M. Validation of the post-delivery perceived stress inventory. Psychology, Health & Medicine. 2014;19(1):70-82.

135. Koch FS, Sepa A, Ludvigsson J. Psychological stress and obesity. The Journal of Pediatrics. 2008;153(6):839-44.

136. Obel C, Hedegaard M, Henriksen TB, Secher NJ, Olsen J, Levine S. Stress and salivary cortisol during pregnancy. Psychoneuroendocrinology. 2005;30(7):647-56.

137. Razurel C, Kaiser B, Dupuis M, Antonietti J-P, Sellenet C, Epiney M. Validation of the Postnatal Perceived Stress Inventory in a French Speaking Population of Primiparous Women. Journal of Obstetric, Gynecologic, & Neonatal Nursing. 2013;42(6):685-96.

138. Abidin RR. Parenting stress index-short form: Pediatric Psychology Press Charlottesville, VA; 1990.

139. Haskett ME, Ahern LS, Ward CS, Allaire JC. Factor structure and validity of the parenting stress index-short form. Journal of Clinical Child & Adolescent Psychology. 2006;35(2):302-12.

140. Moser A, Stuck AE, Silliman RA, Ganz PA, Clough-Gorr KM. The eight-item modified Medical Outcomes Study Social Support Survey: psychometric evaluation showed excellent performance. Journal of clinical epidemiology. 2012;65(10):1107-16.

141. Busby DM, Christensen C, Crane DR, Larson JH. A revision of the Dyadic Adjustment Scale for use with distressed and nondistressed couples: Construct hierarchy and multidimensional scales. Journal of Marital and family Therapy. 1995;21(3):289-308.

142. Crane DR, Middleton KC, Bean RA. Establishing criterion scores for the Kansas marital satisfaction scale and the revised dyadic adjustment scale. American Journal of Family Therapy. 2000;28(1):53-60.

143. Horne JA, Ostberg O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. International Journal of Chronobiology. 1976;4:97-110.

144. Esliger DW, Rowlands AV, Hurst TL, Catt M, Murray P, Eston RG. Validation of the GENEA Accelerometer. 2011.

145. Blake DD, Weathers FW, Nagy LM, Kaloupek DG, Gusman FD, Charney DS. The development of a clinician-administered PTSD scale. Journal of Traumatic Stress. 1995;8(1):75-90.

146. Dubowitz L, Mercuri E, Dubowitz V. An optimality score for the neurologic examination of the term newborn. The Journal of pediatrics. 1998;133(3):406-16.

FIGURES AND TABLES

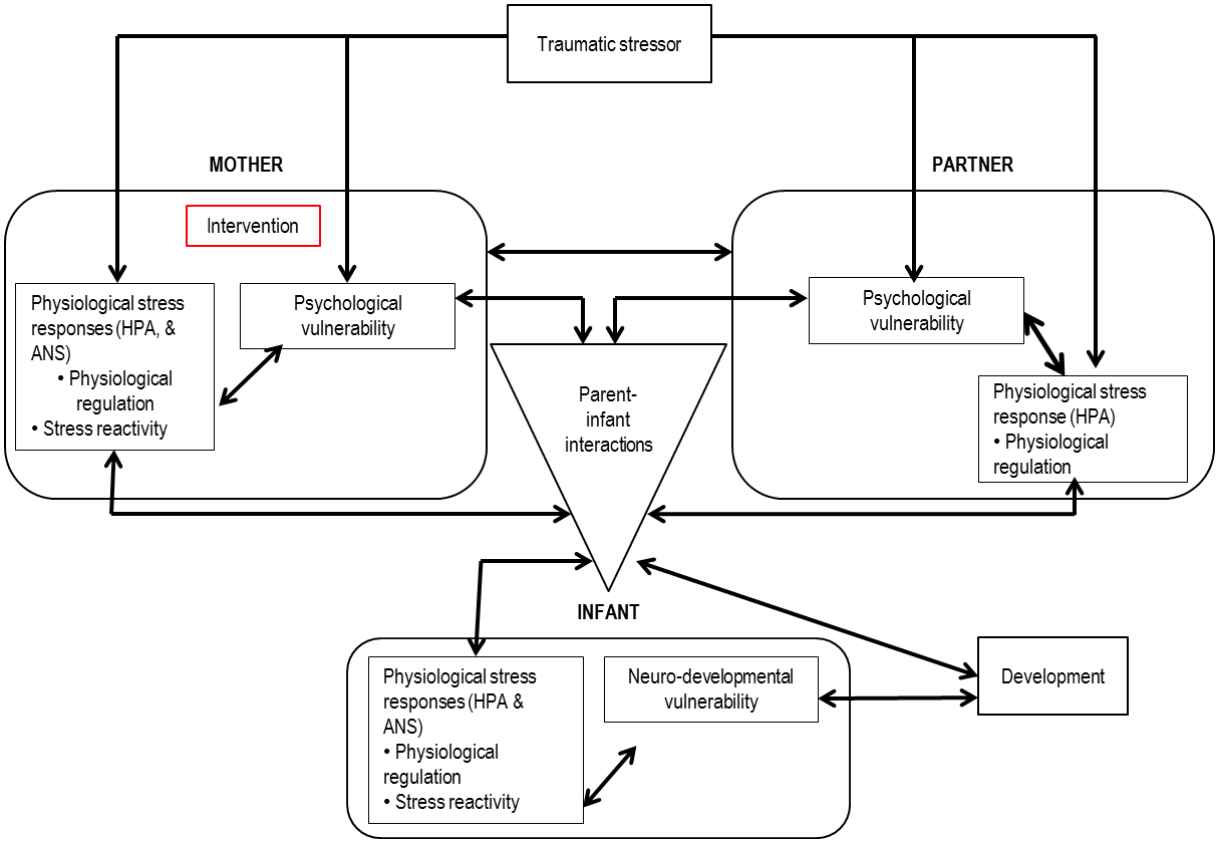


Figure 1. Study variables: Processes in mothers, partner, infants, and their interactions following traumatic childbirth

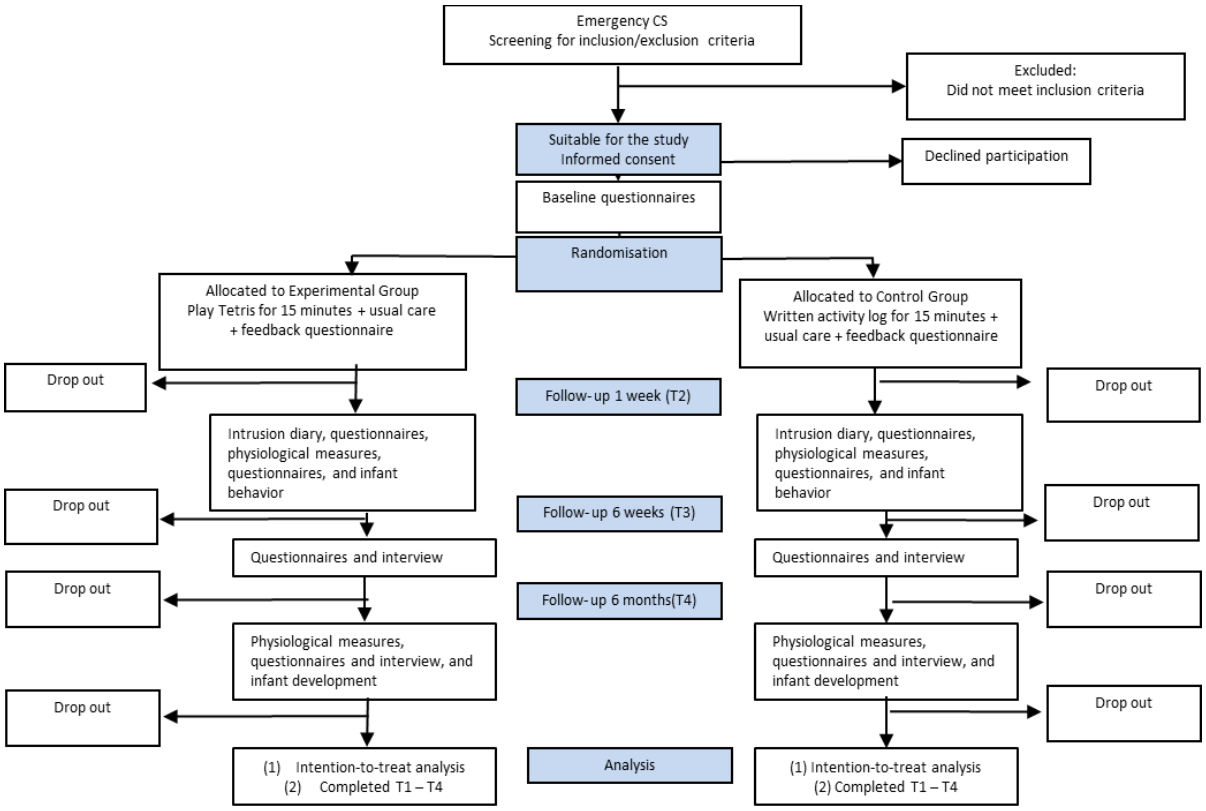


Figure 2. Flowchart of study procedures

Table 1. Overview of primary, secondary and other outcomes, measures, and time points

	DOMAIN	VARIABLES	INSTRUMENTS	TIMING			
				6h after ECS (T1)	≤ 1 week (T2)	6 weeks (T3)	6 months (T4)
MOTHER	Sociodemographic and medical data	Sociodemographic variables	Demographic questionnaire		X	X	X
		Medical data	Obstetric data and pregnancy outcomes from medical records		X		X
			Menstrual cycle (if applicable)				X
			Breastfeeding diary/questions		X	X	X
	Acceptability and expectancy of the intervention	Satisfaction and expectancy	Feedback questionnaire	X			
	Maternal psychological vulnerability	Intrusive trauma-related memories	Trauma-related intrusive memories diary *(4)*		X		
		Stress exposure and perception	Post-delivery Perceived Stress Inventory (PDPSI) (134)		X		
			Major life events (135, 136)		X		X
			Postnatal Perceived Stress Inventory (PPSI) (137)				X
			Parenting Stress Index – Short Form (PSI-SF) (138) (139)				X

	PTSD	Clinician-administered PTSD scale (CAPS) [102]			X	X
		PTSD Checklist (PCL-5) *(101)*			X	X
	ASD	Acute Stress Disorder Scale (ASDS) (105)	X	X		
	Anxiety	Hospital Anxiety and Depression Scale: anxiety subscale (HADS) (107)	X	X	X	X
	Depression	Edinburgh Postnatal Depression Scale (EPDS) *(109)* (109)	X	X	X	X
	Social support	Modified Medical Outcomes Study Social Support Survey (MOS-8) (140)		X	X	X
		Revised Dyadic Adjustment Scale (RDAS) (141) (142)		X	X	X
	Sleep	Pittsburgh Sleep Quality Index Addendum for posttraumatic stress disorder (PSQI-A) (114)			X	X
		Morningness-Eveningness questionnaire (MEQ) (143)		X		
		Pittsburgh Sleep Quality Index (PSQI) (112)		X	X	X
		Sleep diary		X		
		Overnight accelerometer assessments (GENEActiv®)(144)		X		X

	Maternal physiological stress responses	Physiological regulation	Baseline cortisol and cortisol daily profile (saliva)		**X**		**X**
			Resting heart rate and heart rate variability (Firstbeat Bodyguard 2)				**X**
		Physiological stress reactivity	Cortisol (saliva)				**X**
			Heart rate variability (Firstbeat Bodyguard 2)				**X**
PARTNER	Sociodemographic data	Sociodemographic variables	Demographic questionnaire		**X**	**X**	**X**
	Paternal psychological vulnerability	Intrusive traumatic memories	Traumatic intrusions diary *(4)*		**X**		
		Stress exposure and perception	Major life events (135, 136)		**X**		**X**
			Parenting Stress Index – Short Form (PSI-SF) (138, 139)				**X**
		PTSD	Clinician-administered PTSD scale (CAPS) *102* (145)			**X**	**X**
			PTSD Checklist (PCL-5) *(101)*			**X**	**X**
		ASD	Acute Stress Disorder Scale (ASDS) (105)		**X**		
		Anxiety	Hospital Anxiety and Depression Scale: anxiety subscale (HADS) (107)		**X**	**X**	**X**

		Depression	Edinburgh Postnatal Depression Scale (EPDS) (109)		X	X	X
		Social support	Modified Medical Outcomes Study Social Support Survey (MOS-8) (140)		X	X	X
			Revised Dyadic Adjustment Scale (RDAS) (142) (141)		X	X	X
		Perception of ECS-related trauma	Screening questions of the Posttraumatic Diagnostic Scale (94)		X		
		Sleep	Pittsburgh Sleep Quality Index (PSQI) (112)		X	X	X
			Pittsburgh Sleep Quality Index Addendum for posttraumatic stress disorder (PSQI-A)(114)			X	X
			Morningness-Eveningness questionnaire (MEQ) (143)		X		
	Partner physiological responses	Physiological regulation	Cortisol daily profile (saliva)		X		X
INFANT	Sociodemographic and medical data	Sociodemographic variables	Demographic questionnaire (completed by mother)		X	X	X
		Medical data	Neonatal outcomes from medical records		X		
	Infant neurodevelopmental vulnerability	Infant irritability	Dubowitz neurologic examination (146)		X		

	Infant physiological stress responses	Physiological regulation	Baseline cortisol and cortisol daily profile (saliva)				**X**
			Resting heart rate and heart rate variability by (Firstbeat Bodyguard 2)		**X**		**X**
		Physiological stress reactivity	Cortisol (saliva)		**X**		**X**
			Heart rate variability (Firstbeat Bodyguard 2)		**X**		**X**
	Developmental outcomes	Neonatal behaviour	Neonatal Behavioural Assessment Scale (NBAS) (116)		**X**		
		Infant development	Infant Behaviour Questionnaire-revised (IBQ-R) (125)				**X***
			Bayley Scales of Infant Development (Bayley-III; clinician-rated) (126)				**X**
PARENT-INFANT INTERACTION	Mother-infant interaction	Maternal sensitivity	Emotional Availability Scale (EAS, clinician-rated) (123, 124)				**X**
		Bonding	Mother-to-Infant-Bonding Scale (MIBS) (121)		**X**	**X**	**X**
	Partner-infant interaction	Bonding	Mother-Infant-Bonding Scale (MIBS) (121)		**X**	**X**	**X**

Note: * = completed by mothers and partners

Note: * = completed by mothers and partners

Table 2. Other Outcomes and a brief description of the measures used for each outcome. Participant groups for whom the outcome is relevant are highlighted in bold.

Domain	Instruments	Description
Maternal and paternal psychological vulnerability	Morningness-Eveningness Questionnaire (MEQ) (143) (at ≤1 week follow-up)	19 multiple-choice questions self-assessment questionnaire investigating the **mother and partner**'s circadian rhythm. Scores are summed to create a total and a higher score indicates a more 'morning' person.
	Modified Medical Outcomes Study Social Support Survey (MOS-8) (140) (122) (≤1 and 6 weeks, and 6 months follow-up)	8-item self-report questionnaire assessing **mother and partner** social support across four functional support scales: emotional/ informative, tangible, affectionate, and positive social interaction. Items are answered on a 6 point scale (0= *Never*, 5 = *Always*).
	Revised Dyadic Adjustment Scale (RDAS) (141, 142) (at ≤1 and 6 weeks, and 6 months follow-up)	14-item self-report questionnaire measuring the **mother and the partner** relationship satisfaction. Three categories are evaluated: consensus, satisfaction and cohesion.
	Parenting Stress Index - Short Form (PSI-SF)(139) (138) (6 months follow-up)	Self-report questionnaire measuring the **mother and partner** parenting stress. It consists of three subscales: parental distress, parent-child dysfunctional interactions, and child difficulties. 36 items are answered on a 1-point Likert scale *(1 = Strongly agree, 5 = Strongly disagree).*

The Post-delivery Perceived Stress Inventory (PDPSI) (134) (at ≤1 week follow-up)	16-item self-report questionnaire assessing **mother's** perceived stress linked to delivery. Each item is a potential stressor the mother may have experienced during or after delivery. Mothers are asked whether they found the items more or less stressful using a 5-point Likert scale *(1=Never, 5=Very often).*
Postnatal Perceived Stress Inventory (PPSI)(137) (at 6 weeks, and 6 months follow-up)	19-item self-report questionnaire assessing **maternal** postpartum perceived stress. Each item relates to a potential stressor they may encounter within the postnatal period. Mothers are asked to indicate whether they were more or less stressed on a 5 point scale (1 = Not at all, 5 = Extremely).
Life Events Questionnaire (135, 136) (at ≤1 week and 6 months follow-up)	15-item self-report scale where **mother and partners** are asked to indicate if they have experienced different major life events and how stressful they found these events. One item allows participants to identify an event not mentioned and one asks if a major life event occurred within the first trimester of pregnancy.
Trauma-related intrusive memories diary *(4)* (at ≤1 week follow-up)	Completed by **partners**; see Measures section for more details.
Clinician-administered PTSD scale (CAPS) *(100)* (at 6 weeks and 6 months follow-up)	Completed by **partners**; see Measures section for more details.
PTSD Checklist (PCL-5) *(101)* (at 6 weeks and 6 months follow-up)	Completed by **partners**; see Measures section for more details.

	Acute Stress Disorder Scale (ASDS) (105) (at ≤1 week follow-up)	Completed by **partners**; see Measures section for more details.
	Edinburgh Postnatal Depression Scale (EPDS) (109) (at ≤1 and 6 weeks, and 6 months follow-up)	Completed by **partners**; see Measures section for more details.
	Anxiety subscale of Hospital Anxiety and Depression Scale (HADS) (107) (at ≤1 and 6 weeks, and 6 months follow-up)	Completed by **partners**; see Measures section for more details.
	Pittsburgh Sleep Quality Index (PSQI) (112) (at ≤1 and 6 weeks, and 6 months follow-up)	Completed by **partners; s**ee Measures section for more details.
	Pittsburgh Sleep Quality Index Addendum for posttraumatic stress disorder (PSQI-A) (114) (at 6 weeks and 6 months follow-up)	Completed by **partners**; see Measures section for more details.
	Perception of ECS-related trauma (at ≤1 week follow-up)	**Partners** complete the 4 screening questions of the Posttraumatic Diagnostic Scale (94)
Partner physiological regulation	Cortisol daily profile (at ≤1 and 6 months follow-up)	Completed by **partners**; see Measures section for more details.
Partner-infant interaction	Mother-to-Infant-Bonding Scale (MIBS) (121) (at ≤1 and 6 weeks, and 6 months follow-up)	Adapted for partners, **s**ee Measures section for more details
Demographic Information	Partner demographics (at ≤1 and 6 weeks, and 6 months follow-up)	Adapted for partners, **s**ee Measures section for more details
	Infant demographics (at ≤1 and 6 weeks, and 6 months follow-up)	**Mothers** report on their child's weight and height.
Medical data	Breastfeeding diary and questions (at ≤1 and 6 weeks, and 6 months follow-up)	**Mothers** report on breastfeeding in a 2-day daily diary including breastfeeding length and type (exclusive or mixed).
Acceptability and expectancy of the intervention	Self-report questionnaire of satisfaction and acceptability of the intervention (at ≥6 hours following ECS)	On completing the intervention activity, **mothers** complete 7 items to assess intervention fidelity, satisfaction and acceptability of the intervention.

Infant neurodevelopmental vulnerability	Dubowitz neurologic examination (146) (at ≤1 week follow-up)	Examination of the **infant** on 34 items subdivided into 6 categories (tone, tone patterns, reflexes, movements, abnormal signs, and behavior). Full examination by a pediatrician follows standardised instructions and takes 10-15 minutes.

8.2. Appendix B

The Lausanne Infant Crying Stress Paradigm: Validation of an Early Postpartum Stress Paradigm with Women at Low- *vs.* High-Risk of Childbirth-related Posttraumatic Stress Disorder[4]

Vania Sandoz[1], Suzannah Stuijfzand[1], Alain Lacroix[1], Camille Deforges[1], Magali Quillet Diop[1], Ulrike Ehlert[2], Marius Rubo[3], Nadine Messerli-Bürgy[3†], and Antje Horsch[1,4†*]

[1]Institute of Higher Education and Research in Healthcare (IUFRS), University of Lausanne, Lausanne, Switzerland; Vania.Sandoz@bluewin.ch (V.S.); Suzannah.Stuijfzand@protonmail.com (S.S.); Alain.Lacroix@chuv.ch (A.L.); Camille-Deforges@hotmail.fr (C.D.); Magali.QuilletDiop@gmail.com (M.Q.D.); Antje.Horsch@chuv.ch (A.H.)

[2]Department of Clinical Psychology and Psychotherapy, University of Zurich, Zurich, Switzerland; U.Ehlert@psychologie.uzh.ch (U.E.)

[3]Clinical Child Psychology & Biological Psychology, University of Fribourg, Fribourg, Switzerland; Marius.Rubo@unifr.ch (M.R.); Nadine.Messerli@unifr.ch (N.M-B.)

[4]Neonatology Service, Department Woman-Mother-Child, Lausanne University Hospital and University of Lausanne, Lausanne, Switzerland

[†] Joint last authors

*Correspondence: Antje.Horsch@chuv.ch ; Tel.: +4179-556-0750

[4] Sandoz V , Stuijfzand S, Lacroix A, Deforges C, Quillet Diop M, Ehlert U, et al. The Lausanne Infant Crying Stress Paradigm: Validation of an Early Postpartum Stress Paradigm with Women at Low - vs. High-Risk of Childbirth-related Posttraumatic Stress Disorder. J Pers Med. 2021;11(6):472.

ABSTRACT

Stress reactivity is typically investigated in laboratory settings, which is inadequate for mothers in maternity settings. This study aimed at validating the Lausanne Infant Crying Stress Paradigm (LICSP) as a new psychosocial stress paradigm eliciting psychophysiological stress reactivity in early postpartum mothers (n=52) and to compare stress reactivity in women at low- (n=28) *vs.* high- risk (n=24) of childbirth-related posttraumatic stress disorder (CB-PTSD). Stress reactivity was assessed at pre-, peri-, and post-stress levels through salivary cortisol, heart rate variability (high frequency (HF) power, low frequency (LF) power, and LF/HF ratio), and perceived stress via a visual analogue scale. Significant time effects were observed for all stress reactivity outcomes in the total sample (all p<.01). When adjusting for perceived life threat for the infant during childbirth, high-risk mothers reported higher perceived stress (p<.001, d=0.91), and had lower salivary cortisol release (p=.023, d=0.53), lower LF/HF ratio (p<.001, d=0.93), and marginally higher HF power (p=.07, d=0.53) than low-risk women. In conclusion, the LICSP induces subjective stress and autonomic nervous system (ANS) reactivity in maternity settings. High-risk mothers showed higher perceived stress and altered ANS and hypothalamic–pituitary–adrenal reactivity when adjusting for infant life threat. Ultimately, the LICSP could stimulate (CB-)PTSD research.

Keywords: PTSD; cortisol; heart rate variability; stress reactivity; childbirth; TSST; postpartum; women; mothers; perceived stress

INTRODUCTION

Childbirth-related posttraumatic stress disorder

Posttraumatic stress disorder (PTSD) may develop following a traumatic event, as defined by the PTSD stressor criterion of the Diagnostic and Statistical Manual of Mental Disorders, 5th ed., (DSM-5) (1). Four symptom clusters (criteria B-E of the DSM-5) characterize this disorder: intrusions, avoidance of trauma-related cues, negative cognitions and mood, and hyperarousal (1). PTSD can be diagnosed one month following the traumatic stressor (1), even if an acute posttraumatic stress response can be observed in the meantime (2). The question arises to understand why after having been exposed to a traumatic event, only some individuals develop PTSD symptoms (3). According to psychobiological findings, altered stress reactivity, such as a dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis or the autonomic nervous system (ANS), may play a major role in the development of PTSD (4, 5).

Up to one-third of mothers report perceiving giving birth as traumatic (6-8) and may develop childbirth-related PTSD (CB-PTSD) (9, 10). According to the DSM-5 PTSD stressor criterion, perceived life threat is a key element contributing to the traumatic appraisal of childbirth (1). Therefore, mothers who fear for their life or their physical integrity, or the ones of their infant during childbirth are at higher risk of CB-PTSD compared to those who did not (1, 11). In community samples, 3-4% of women reach the clinical threshold for CB-PTSD (12, 13), whereas in high-risk samples, CB-PTSD prevalence rates increase up to 16-19% (12, 13). Studies investigating the relationships between CB-PTSD and traumatic childbirth experience and parity reported inconsistent results (14-17) Although traumatic childbirth perception depends on the maternal subjective appraisal of the event, objective elements, such as obstetric or neonatal complications, can worsen the traumatic experience (11).

There are several arguments to assume that CB-PTSD might differ from PTSD by the nature of its trauma (18, 19). As a positive and expected life event, childbirth is generally perceived positively by the society. Mothers might be terrified not only for themselves but also for their infant, which differs from other traumatic events. The perceived life threat for the infant is a strong predictor of CB-PTSD (17). Accordingly, mechanisms involved in the development of CB-PTSD might be different from the ones of PTSD following other traumatic events.

Besides the maternal distress and interference with everyday functioning due to CB-PTSD symptoms (9), CB-PTSD can negatively affect the couple relationship (20, 21) and subsequent future reproductive experiences (22, 23).

Maternal CB-PTSD symptoms may also be associated with child sleep problems (22, 24), breastfeeding initiation and continuation (22, 25), and, potentially, with problems regarding the mother-infant relationship or bonding (22, 26).

To date, evidence-based interventions to prevent CB-PTSD are lacking (27). Given the significant consequences of CB-PTSD on mothers and their families, it is fundamental to better understand the underlying physiological mechanisms that play a role in the development of CB-PTSD, as this may open up options for the early assessment and treatment of CB-PTSD (28).

Psychophysiological stress reactivity and posttraumatic stress disorder

The stress response system is composed of the sympathetic (SNS) and the parasympathetic (PNS) branches of the ANS, and the HPA axis (29). Under stress conditions, HPA activation increases (elevation of cortisol release), whereas PNS activation withdraws (reduction of high frequency (HF) power), and SNS activation intensifies (increase of low frequency (LF) power), resulting in a short-term imbalance of the ANS (assessed by LF/HF ratio) (29). Cortisol release peaks at 10 to 30 min after stress exposure, whereas changes of SNS and PNS activation are seen more immediately earlier (29). Cortisol is released to mobilize physiological and psychological resources of the organism, and to support recovery by counteracting the physiological effects of the SNS activation (29). Cortisol release gradually increases during pregnancy, with a peak at the end of the pregnancy, and then returns to nongravid levels 12-24 hours after childbirth (30-33). There is evidence that early postpartum conditions can have an additional impact on cortisol release, such as breastfeeding within the last hour that causes blunted cortisol stress reactivity (34).

Overall, the literature suggests that the development and maintenance of PTSD is related to an HPA dysregulation (35). Individuals exposed to trauma or with PTSD show mainly blunted stress responses (35-38), and only one study with childhood abuse-related PTSD in women showed elevated salivary cortisol responses following exposure to traumatic reminders compared to women with a history of childhood abuse but without PTSD (39). However, given the small sample size (n = 12 per group) and the unstandardized stress procedure, the interpretation of these findings requires caution. All other studies reported blunted cortisol reactivity in response to laboratory stress induction (e.g., Trier Social Stress Test (TSST), Emotional Stroop task), including a study on US female veterans compared to civilian women, regardless of their PTSD status (38), or in postpartum women with

emotion regulation difficulties and a history of child maltreatment (37). Similar results were found in mothers suffering from interpersonal violence-related PTSD at 12 and 48 months postpartum (40).

PTSD patients had altered ANS responses at rest compared to controls in a meta-analysis (i.e., reduced HF and LF power, with a higher reduction in HF than LF, and increased LF/HF ratio), indicating that the cardiovascular system cannot properly adapt to external and internal demands (5). Further, in response to lab-based stress tasks, individuals showed an increase of SNS, a decrease of PNS activation, as well as a short-term imbalance of the ANS (41-43). As far as we know, there is no study that investigated early postpartum mothers with a traumatic childbirth experience who might be at risk of CB-PTSD, even though hormonal changes linked to childbirth might influence ANS and HPA activation. It furthermore remains unclear whether the physiological changes can already be expected early after trauma at a time point where PTSD is not yet established. In addition, stress also provokes a psychological stress response, such as perceived stress (44, 45). To our knowledge, no study has yet investigated early perceived stress reactivity in women following traumatic childbirth or in individuals at risk of CB-PTSD.

The current study

Assessment of stress responses during the early post-partum is limited due to the physical and psychological constrains of the early postpartum period in women (e.g., standing up during the stress phase can be physically impossible and pretending to be in a job interview, as it is used in standard lab-based stress tasks, is likely to be far from maternal concerns during the days following childbirth) (46-48). Nevertheless, studying psychophysiological stress reactivity in mothers during the early postpartum period could be relevant to identify CB-PTSD risk factors and to clarify physiological mechanisms underlying the development of CB-PTSD (35).

Therefore, the current study firstly aimed to provide first evidence for the validation of a new stress paradigm, the *Lausanne Infant Crying Stress Paradigm (LICSP)* for the early postpartum period. More specifically, we hypothesized a psychophysiological stress response to the LICSP (i.e., increase of salivary cortisol release, reduction of HF power, increase of LF power, increase of LF/HF ratio, and increase of perceived stress).

Given that the general PTSD literature reported altered physiological stress reactivity in traumatised individuals, this study secondly intended to investigate group differences in psychophysiological stress reactivity in women at low- *vs.* high-risk of CB-PTSD in the early days following childbirth. However, given that stress reactivity has never been studied shortly after the traumatic stress exposure, exploratory analyses were conducted for group

differences.

MATERIALS AND METHODS

Design and study population

This cross-sectional experimental study took place on the postpartum ward of the maternity unit of a Swiss university hospital between December 2018 to December 2019. The following inclusion criteria were applied: (a) being ≥ 18 years old, (b) having given birth to a live baby at ≥ 34 weeks of gestation during the ≤ 5 days, (c) having given written consent, and (d) obtaining a certain score in response to screening questions that allowed the allocation to the group at low- *vs.* high-risk of CB-PTSD. For this purpose, willing mothers answered screening questions consisting of two items related to perceived life threat during childbirth (based on PTSD stressor criteria of DSM-5) (1, 18, 49). Responses were scored on a 7-point Likert scale (1 = *not at all* to 7 = *extremely*): "Did you think that your life was in danger?" "Did you think that your baby's life was in danger?" To be included in the study, low-risk participants had to respond ≤2 to each of the two items, whereas high-risk participants had to score ≥4 to one of the two items. The reason for such classification was to ensure participants were either not traumatized or sufficiently traumatized to find group differences. Exclusion criteria included (a) insufficient French language skills, (b) established intellectual disability or psychotic illness, (c) antenatal corticosteroids administration, (d) current alcohol abuse and/or illegal drug use, (e) severe maternal and/or infant illness, and (f) infant hospitalized in neonatal intensive care unit. The total sample consisted of 52 participants, with 28 mothers in the low-risk and 24 in the high-risk group.

As part of the Swiss TrAumatic biRth Trial (START) (18), this study was conducted in accordance with the Declaration of Helsinki, and was approved by the local ethics committee for research in humans (study number 2017-02142). Before enrolling in the current study, participants received an information sheet and gave written consent. The current study was written up according to the STROBE reporting statements (50).

Procedure and Measures

The Lausanne Infant Crying Paradigm procedure

The LICSP development was based on the principal components of the TSST, which is the gold standard paradigm to induce physiological stress responses in adults (46-48). The LICSP procedure comprised a baseline phase, a

stress phase, and a recovery phase, ending with an 8-min optional guided relaxation. Both the baseline and the recovery phases lasted 40 min, whereas the stress phase lasted 20 min.

Mothers were encouraged to breastfeed and were asked to have lunch before starting the LICSP at 1pm. Visitors were prohibited during the whole LICSP procedure, which coincided with the time the maternity did not allow other visitors than partners (outside of public visiting hours). During the baseline and the recovery phases, participants were instructed to rest in their hospital bed with their baby around and their partner (if they were present). During the stress phase, participants were alone in a separate consultation room sitting at a desk and facing an unknown female experimenter that observed them, gave them instructions, and adopted a neutral facial attitude (47). All participants were filmed on the pretext that their facial expressions and their stress coping skills would be analysed by specialists. The stress phase consisted of a 3-min anticipation of the infant crying test (ICT), the ICT being a psychosocial stressor, and a surprise mental arithmetic task as a cognitive stressor (47). The ICT involved differentiating one's own infant crying among several recordings of infant crying. The experimenter read instructions implying that mothers usually differentiate their infant's crying from those of others, which can threaten the social self of participants and induce stress (46, 51). Actually, mothers can recognize their own infant crying already at 24 hours postpartum, but cannot differentiate it from other infant crying (52). The instructions of the surprise mental arithmetic task did not differ from the ones used in the TSST (47).

The ICT was designed and run with E-Prime 3.0 software (Psychology Software Tools, Pittsburgh, PA). Five 20-sec recordings of infant crying were first played to participants through headphones, followed by 14 other 10-sec infant crying recordings. Between each infant crying recording, participants had 3 sec to indicate by pressing on specific keyboard keys whether this was their own infant crying or not. Among the 19 infant crying clips, one of 10-sec length and another of 20-sec were from the participant's own infant. Those two crying clips were recorded prior to the LICSP during a routine care episode (e.g., diaper change, bath) in the absence of the participant.

Both the psychosocial and cognitive stressors contained main evidence-based characteristics required to elicit psychosocial stress: anticipation, novelty and/or unpredictability, social-evaluative threat, uncontrollability, and motivated performances (46, 47, 53). Figure 1 illustrates the LICSP procedure, including time points of measurements. At the end of the recovery phase, a guided relaxation was offered to participants, followed by a moment to debrief to ensure no side effects would result from the stress phase. Finally, participants completed a

set of questionnaires (see section 2.3.3) right after the LICSP or during their stay on the postpartum ward.

***Psychophysiological stress* responses**

Given that saliva collection does not induce additional stress, and is non-invasive and reliable, salivary cortisol was chosen as a measure of the HPA activity in response to stress (54, 55). As illustrated in Figure 1, saliva was obtained using salivettes (Sarstedt, Sevelen, Germany) 5 min before the start of the stress phase (C1) and directly after the 3-min anticipation of the ICT (C2). Five additional samples were collected during the recovery phase at 10 min intervals (after the stressor and during early, mid and late recovery, and at the end of the paradigm (C3 to C7). The timing of salivary collection is consistent with the standardized protocol of the TSST, with a salivary cortisol peak response expected between 10 and 30 min post-stress (i.e., C4 to C6) (29, 47). Participants were instructed not to eat, drink, have a chewing gum, or brush teeth within 30 min before saliva collection. After chewing the cotton wool during 60 sec, salivary samples were stored at ≤ 20°C until they were sent for analysis to the biochemical laboratory of the Clinical Psychology and Psychotherapy Department at the University of Zurich, Switzerland. Cortisol levels (nmol/L) were analyzed using luminescence immunoassay based on the competition principle (IBL, Hamburg, Germany). Inter- and intra-assay coefficients of variance of cortisol were ≤ 5%.

Cardiac activity was measured continuously via an ECG device Firstbeat Bodyguard 2© (Firstbeat Technologies Ltd., Jyväskylä, Finland). During the 3-min recordings of the baseline (i.e., HF1, LF1, and LF/HF1) and recovery (i.e., HF4, LF4, and LF/HF4) phases, participants were instructed to rest in their hospital beds and were allowed to be with their baby. The Kubios HRV Standard software (ver. 3.2.0) was used to graphically display the cardiac activity in order to spot outliers. Data quality was assessed by inspecting the normality of interbeat intervals (IBI values) for each recording and by comparing HRV metrics with and without the Kubios' artifact correction algorithm applied (set to medium). Data quality was high in all recordings and no artifact correction was therefore necessary. Frequency-domain HRV parameters (i.e., HF power, LF power, and LF/HF ratio) were calculated using Fast Fourier Transformation. LF power (range: 0.04-0.15 Hz) reflects mainly SNS activation, whereas the HF power (range: 0.15 to 0.4 Hz) echoes the PNS activation (41, 43). The LF/HF ratio illustrates the balance of SNS and PNS activity (41, 43).

Perceived stress was measured repeatedly at 10 times via a visual analogue scale (VAS) rating from 1 = *not at all stressed* to 5 = *extremely stressed* (Figure 1) (56). Perceived stress was assessed at the beginning and the end of

the baseline phase, during the stress phase, at the end of the anticipation period and of the psychosocial and cognitive stressors, and finally, during recovery at each time point of saliva sampling.

Psychosocial and medical information

Perceived life threat for the mother and the infant during childbirth were measured via the screening questions (see section 2.1). To situate the sample and given that depression is frequent and comorbid with acute stress during the early postpartum period (57), depression was assessed via the Edinburgh Postnatal Depression Scale (EPDS) (58). This self-report questionnaire assesses the severity of postnatal depression symptoms over the past week (58). A sentence was added to instructions stating that researchers were particularly interested in how mothers feel since childbirth. The 10 items are scored on a 4-point Likert scale (0-3), with a total score ranging from 0 to 30 (58). A higher score suggests a higher level of symptom severity (58). The French version has demonstrated satisfying psychometric proprieties (59). A good internal consistency was observed in the present study (Cronbach's $\alpha = 0.85$) and was slightly higher than previously reported in postpartum mothers of Switzerland (60, 61).

Since anxiety is also common in the early postpartum period and comorbid with acute stress (57), anxiety was measured through the anxiety subscale of the Hospital Anxiety and Depression Scale (HADS-A). This 7-item self-report questionnaire retrospectively measures the severity of anxiety symptoms within the week preceding childbirth, using a 4-point Likert (0-3) scale that ranges from 0 to 21 (62). Higher scores indicate greater symptom severity (62). The French version has shown good psychometric characteristics (63) with Cronbach's alpha of 0.72, which is similar to previous studies of Swiss postpartum women (57, 64).

Participants responded to psycho-sociodemographic questions on age, civil status, education level, and smoking habits. Parity, gravidity, and type of delivery were retrieved from medical records. In addition, a dichotomous variable was created depending on whether the participant breastfed over the 60 min preceding the stress phase (*yes* = 1, *no* = 2).

Evaluation of the stress phase of the Lausanne Infant Crying Stress Paradigm

After the LICSP and as a manipulation check, participants were asked to evaluate the stress phase with a 100-point Likert scale (0 = *not at all*, 50 = *moderately*, 100 = *extremely*) according to the following parameters: novelty, difficulty, stress, controllability and predictability (46, 53).

Sample size calculation

Given that the LICSP is a new stress paradigm, no prior data existed for an a priori power calculation Therefore, a sample size of N = 40 was estimated based on previous studies using the TSST (i.e., the gold standard stress paradigm) (38, 47, 65). The current study consequently aimed to include 50 mothers completing the LICSP procedure to account for a potential lower effect of the LICSP.

Data analysis

All the statistical analysis were carried out using R v3.6.1 (running under RStudio v1.1.463) (66). The salivary cortisol levels of two participants were missing for C1, as well as the perceived stress ratings of one participant for the last assessment (VAS10). Given this missing data represented <30% of the dataset, they were imputed using Bayesian linear regression (NORM) for numerical values. The missing data imputation was performed by the mice package v3.11.0 algorithms (67). Due to technical issues, the cardiac activity of one participant during the stress phase was missing. Given that more than 30% of her data were missing, these data were not imputed. Further, seven participants did not entirely perform the mental arithmetic task, but HRV data were not imputed.

Results were considered as significant at $p < 0.05$. Descriptive differences between the low *vs.* high risk groups were assessed with the appropriate statistical tests, namely the Chi square (X^2), the Fischer's exact test (p), or the Mann-Whitney test (W). Given that data did not meet assumptions for a two-way repeated measures analysis of variance (ANOVA; group*time), the aligned ranks transformation repeated measures ANOVA (ART ANOVA; group*time), i.e., a non-parametric test was carried out. To assess stress reactivity to the LICSP, pairwise comparisons with Tukey adjustments were conducted as post-hoc tests to determine differences between relevant pair groups. Effect sizes (Cohen's d) were calculated. Finally, one-way analyses of covariance (ANCOVAs) were conducted to determine differences between low- *vs.* high-risk groups on psychophysiological stress responses, using perceived life threat for the infant as a covariate. Results are reported as unadjusted and adjusted for perceived life threat for the infant. Given the potential impact of breastfeeding on salivary cortisol activity, an additional exploratory ANCOVA was carried out for this outcome. Note that, given the inconsistent literature on CB-PTSD or traumatic childbirth experience and parity, parity was not considered as a covariate in the current paper (14-17). Finally, cortisol levels were expected to be low at C1 and C2. However, as shown in Table 1, participants showed elevated cortisol release at C1. Therefore, C2 was considered as a baseline value for all the statistical analyses.

RESULTS

Characteristics of the sample and of the Lausanne Infant Crying Stress Paradigm

The study was presented to *n* = 195 mothers, of whom *n* = 72 accepted to answer the screening questions. Main reasons for declining participation were being tired, imminent return home, or being unavailable at the time of the LICSP. Of those who participated in the screening process, *n* = 20 had a screening score that did not allow their group allocation, i.e., the perceived life threat of these women was not sufficiently low or high for them to continue with the study. The final study sample included *n* = 24 mothers at high-risk of CB-PTSD and *n* = 28 CB-PTSD low-risk mothers. Two participants from the low-risk condition stopped the experiment after the stress phase and did not complete the recovery period.

Sociodemographic, medical, and psychological characteristics of the sample are presented in Table 2. The high-risk group reported a greater perceived life threat for the mother ($p = 0.002$) and for the infant ($p < 0.001$). The low- and high-risk groups significantly differed in the type of delivery, with more vaginal births and planned caesarian sections for the former, and more operative vaginal births and emergency caesarian sections for the latter ($p < 0.001$). Further, low-risk mothers had a significant higher parity ($p = 0.022$) and gravidity ($p = .013$) than high-risk mothers. As illustrated in Table 3, no significant group difference was observed regarding procedural characteristics of the LICSP. The baseline phase lasted on average 44 min (*SD* = 3 min), the stress phase 22 min (*SD* = 3 min), and the recovery phase 43 min (*SD* = 4 min).

Salivary cortisol response to psychosocial stress

Table 1 shows the characteristics of the salivary cortisol assessments during the LICSP. Analyses revealed a significant time effect ($F(5, 250) = 4.84$, $p < 0.001$) for salivary cortisol (Figure 2). Salivary cortisol increase between C2 (baseline) and C4 (expected peak response within early recovery period, 10 min post-stress) was not significant ($p = 0.94$, $d = 0.01$), but a significant difference was observed between baseline (C2) and recovery period C7 (end of paradigm, $p = 0.027$, $d = -0.21$) and within recovery at C5 (20min post-stress) and C7 (end of paradigm; $p = 0.003$; $d = -0.27$), revealing that cortisol was high at baseline and kept the same level up to the expected peak time point and reduced afterwards. There was a significant and moderate group effect when controlling for the perceived life threat for the infant ($F(1, 309) = 5.20$, $p = 0.023$, $d = 0.53$), with mothers of the high-risk condition showing slightly lower adjusted mean level of salivary cortisol (M = 4.26, SD = 1.96) than the ones of the low-risk group (M = 5.44, SD = 2.40). Further, an exploratory ANCOVA examining the role of breastfeeding showed no significant

group effect on salivary cortisol levels.

ANS response to psychosocial stress

ANS properties during the LICSP including HF power, LF power, and LF/HF ratio are displayed in Table 1. A significant time effect was observed for HF power ($F(3;142.47) = 4.59$, $p = 0.006$) (Figure 2), with a significant increase of HF power from the baseline (i.e., HF1) to the cognitive stressor (i.e., HF3) ($p = 0.004$, $d = 0.21$), followed by a HF power decrease during the recovery (i.e., HF4) ($p = 0.066$, $d = -0.20$). A moderate group effect was found for HF power when controlling for the perceived life threat for the infant ($F(1;197) = 3.32$, $p = 0.07$, $d = 0.53$). Mothers at risk of CB-PTSD showed higher adjusted mean of HF power ($M = 508.01$, $SD = 351.36$) than women at low-risk ($M = 287.79$, $SD = 469.47$).

Regarding LF power, a significant time effect was observed ($F(3;143.26) = 14.39$, $p < 0.001$) (Figure 2). From the baseline (i.e., LF1) to the cognitive stressor (i.e., LF3), LF power significantly increased ($p < 0.001$, $d = 0.77$), before significantly decreasing during the recovery (i.e., LF4) ($p < 0.001$, $d = -0.78$) showing medium to large effect sizes. No significant group effect on mean of LF power was detected, even when adjusting for the perceived life threat for the infant.

There was a mean LF/HF ratio time effect ($F(3;143.47) = 10.42$, $p < 0.001$) (Figure 2) with a decrease between baseline (LF/HF1) and the psychosocial stressor (i.e., LF/HF2, $p = 0.002$, $d = -0.29$) and an increase to the cognitive stressor (i.e., LF/HF3, $p < 0.001$, $d = 0.54$). The group effect for the mean LF/HF ratio was large, and only significant when controlling for the perceived life threat for the infant ($F(1, 197) = 10.84$, $p < 0.001$, $d = 0.93$), with mothers of the high-risk condition showing a lower adjusted mean of LF/HF ratio (M = 1.59, SD = 2.16) than the ones of the low-risk group ($M = 3.95$, $SD = 2.83$).

Perceived stress in response to psychosocial stress

A significant time effect was reported for perceived stress ($F(9; 450) = 43.10$, $p < 0.001$) (Figure 2). Perceived stress from the baseline, i.e., VAS2, increased during the psychosocial and cognitive stressors (VAS4: $p < 0.001$, $d = 1.36$; VAS5: $p < 0.001$, $d = 1.84$), and then reduced during recovery, i.e., VAS8 ($p < 0.001$, $d = -1.79$). The group effect was large and significant when controlling for the perceived life threat for the infant ($F(1, 517) = 25.89$, $p < 0.001$, $d = 0.91$), but not otherwise. Hence, high-risk mothers reported more perceived stress ($M_{adjusted} = 2.55$, $SD_{adjusted} = 1.17$) than low-risk mothers during the LICSP ($M_{adjusted} = 1.53$, $SD_{adjusted} = 1.07$).

DISCUSSION

Changes of psychophysiological stress responses occurring during the early postpartum period after a traumatic childbirth have not been investigated so far. However, these changes might play a significant role in the development of CB-PTSD. In this study, first evidence for the validation of a new stress paradigm, namely the LICSP, was collected regarding the ANS and subjective stress responses of mothers in the early postpartum period (2-3 days after childbirth).

Results revealed that the LICSP elicits ANS and subjective stress responses in women in the early postpartum period. Mothers perceived increased levels of stress and an increase of LF power, which corresponds with primary SNS activation as a response to the stress task. In parallel, HF power representing PNS activation also increased during the stress task, which did not correspond with our expectations. Further, salivary cortisol did not change in response to the stress task, but maintained at an increased level that already existed before the stress induction up to the expected peak time point in response to the stress task and declined afterwards, showing significantly lower levels at the end of the paradigm than at baseline.

Further, the results of this study revealed higher perceived stress, higher HF power, and lower LF/HF ratio in the high-risk group when controlling for the role of the perceived life threat for the infant, with moderate to large effect sizes. Although these results need to be replicated, these group differences hint at future possibilities of identifying distinct early stress responses in mothers at high risk of developing CB-PTSD, with important implications for the early identification of those potentially in need of professional support.

In sum, the LICSP revealed stress responses to the new paradigm in the total sample of postpartum mothers. There was no increase of salivary cortisol in response to the LICSP, as mothers showed increased levels of cortisol already at baseline. Reasons for this could be diverse but are likely to be linked to the anticipation of participating in a study. First, mothers were instructed to breastfeed and have lunch before the start of the LICSP at 1pm. Managing these requirements, as well as the demands related to the early postpartum period (e.g., maternal and newborn care, hospital schedule for lunch) might have been a source of stress, augmenting the mean baseline salivary cortisol level. In addition, given that mothers knew they would be separated from their infant during the upcoming stress phase, they might have been more stressed by anticipating this moment. Therefore, assessment after the anticipation period (C2) showed lower cortisol levels than during the baseline (C1) and remained higher

than expected until after the expected peak in relation to the stress task. Potentially, an appropriate salivary cortisol baseline could have been obtained by prolonging the baseline period.

Overall, the mean cortisol levels observed in the current sample were higher than what was previously observed in traumatized *vs.* non-traumatized women (38). In the early postpartum period, various confounders might have influenced HPA activation, including sleep deprivation and parenting challenges after birth (45, 68-70). Regarding the cortisol reactivity, estrogen, progesterone, oxytocin and prolactin are known to play a major role in the initiation and maintaining of lactation and might blunt or reduce HPA activation during a stress task (71, 72). A study reported diminished blood cortisol reactivity in lactating women at 2 months postpartum (73). In contrast, cortisol levels in our sample were increased. This discrepancy could be the result of the fact that assessment took place only a few days after childbirth when the lactation was only initiated, which is a different stage of the postpartum period and therefore difficult to compare. Further, cortisol levels could have been affected by hormonal conditions related to the previous pregnancy state, but there is evidence shows that maternal salivary cortisol should return to pre-pregnancy levels already at 12-24 hours postpartum (31, 32).

Another reason for these results could be that the overall level of stress during the stress phase may not have been sufficiently intense to further activate the HPA axis (29). The limited social-evaluative threat (i.e., when some part of the self is judged by others) might have caused less HPA activation during the LICSP (46), as, contrary to the stress phase of the TSST that contains a panel of experimenters (47), the stress phase of the LICSP includes only one experimenter. Therefore, the single experimenter might have had less social-evaluative impact, and therefore limited the cortisol release. Further, the absence of a face-to-face feedback of the experimenter on the participant's performance during the ICT may have decreased the social-evaluative threat (74).

The results clearly showed an increase in perceived stress and LF power, a marker for SNS activation under stress, and an unexpected parallel increase of HF power. This is contrary to a previous study with pregnant women revealing HF power withdrawal, a decreased LF/HF ratio but no change of LF power (42). Given that following childbirth, the HPA activation changes back to non-pregnant stages, similar returns to a non-pregnant stage of ANS activation could have been expected (31, 32, 75). However, an examination of the HF response pattern revealed an increase of HF power in the total sample, and particularly in the high-risk group. This could be related to the pain condition after birth caused by compensatory sympatho-adrenal activation that includes catecholamine release into

the circulation system (76) in the total sample, which may result in parallel activation of SNS and PNS. It does not, however, explain the difference between the high- and low risk groups. Interestingly, a previous study reported a similar increase in maternal PNS activation during a stress task that caused ruminations in relation to the threat of being separated from the child (77). This co-activation of SNS and PNS in the high risk group could be related to the levels of hypervigilance after the trauma (77), and could have caused contradictory PNS elevation during the task as mothers, while listening to infants' crying, might have had ruminations linked to their baby's wellbeing.

Moderate and large effects were found for differences between high and low-risk groups in relation to other physiological stress responses. We therefore conclude that, when controlling for the infant life threat, mothers at high risk of CB-PTSD report more perceived stress and show altered ANS and HPA activation during a stress task within the first days after childbirth. Psychophysiological stress mechanisms potentially involved in CB-PTSD development seem to be differently affected according to whether a danger was perceived for the mother or the infant during childbirth. This is not surprising given that an admission to neonatal intensive care is a predictor of CB-PTSD (78). This assumption is supported by recent evidence showing that PTSD and CB-PTSD symptomatology differ (78-80). Reassessment after a couple of weeks might reveal a different stress response pattern, particularly regarding the HPA response.

Strengths and limitations

This study addresses a methodological gap in perinatal stress research. To our knowledge, this is the first study that examined physiological stress reactivity in mothers who recently gave birth using a stress paradigm, which allows assessment in a hospital ward context. The development of the LICSP was based on the gold standard of lab-based stress testing, the TSST, which is a robust stress paradigm (46, 47). The sample of this study included mothers at risk of CB-PTSD with lower parity and more operative vaginal deliveries and emergency caesarian sections, which are known to be risk factors for CB-PTSD (13, 14, 17), thus suggesting a good internal validity. The fact that the measurement of stress responses included psychological and physiological, namely both stress branches (HPA axis and ANS), and the application of a standardized procedure (LICSP), are strengths of the study. The manipulation check of the LICSP (Table 3) further revealed that high novelty, high difficulty and low predictability but medium controllability were achieved.

Nonetheless, some limitations must be highlighted. First, the mean salivary cortisol level at baseline (C1) was

higher than expected for a baseline (81). Future research could address this by lengthening the baseline, although the circumstances in this early postpartum period might not allow this to be feasible. Second, early postpartum factors might have influenced stress responses and would need to be assessed in the future (e.g., oxytocin provoking a blunted HPA response) (71-73). Similarly, sleep deprivation (68-70), or lifestyle factors (e.g., history of nicotine, alcohol or caffeine use) (45) could have caused physiological changes, none of which were included here as covariates, given the small sample size. Fourth, potential PTSD symptoms resulting from previous traumatic events were not assessed, which could have impacted on the well-being of postpartum mothers (35, 36). Fifth, this study would have benefitted from the inclusion of a passive control group. Sixth, seven participants stopped the surprise mental arithmetic task before entirely completing it, leading to HRV missing data. To our knowledge, previous studies did not report such details. Consequently, we cannot compare whether this early stress phase termination is higher in our sample than in others populations. Finally, although the screening questions were based on PTSD stressor criteria of DSM-5 and previously used (1, 18, 49, 64), assessing CB-PTSD risk with only these two items is an important limitation, and validated assessment of CB-PTSD risk should be developed to be considered in future studies.

Future research perspectives

The literature suggests that an altered stress activity might play a major role in the development of PTSD, and thus by extension, of CB-PTSD (4, 5). In our study, high-risk mothers perceived higher stress levels and showed altered ANS and HPA activation during the LICSP stress paradigm, when controlling for the perceived infant life threat. Given that important research gaps persist, further studies need to be conducted to better understand these psychological and physiological stress mechanisms at such an early time period after giving birth and how these are linked to the development of CB-PTSD later on. The findings of this study need replication in a larger sample, and the LICSP procedure would benefit from further adaptations, including a change of conditions for the baseline assessment, and improving the psychosocial stressor of the LICSP in order to elicit more intense physiological stress responses. Adding a passive control group is needed to better understand the LICSP's potential in eliciting physiological stress responses. Regarding the utility of the LICSP to identify biomarkers specific to CB-PTSD, longitudinal studies need to be conducted, with CB-PTSD assessment at least one month following childbirth.

AUTHOR CONTRIBUTIONS

Conceptualization, A.H., V.S., N.M-B., S.S., and C.D.; methodology, A.H., V.S., N.M-B., S.S., and C.D.; software,

V.S., A.L., N.M-B., and M.R.; validation, V.S. and A.H.; formal analysis, A.L., and V.S.; investigation, V.S., M.Q.D., and C.D.; resources, A.H., N.M-B, and U.E; data curation, A.L., V.S., and A.H.; writing—original draft preparation, V.S., A.H., and M.Q.D.; writing—review and editing, V.S., A.H., and N.M-B.; visualization, V.S., A.H., and A.L.; supervision, A.H., and N.M-B.; project administration, V.S., M.Q.D., and A.H.; funding acquisition, AH. All authors have read and agreed to the published version of the manuscript.

FUNDING

This research was funded by a project grant to A.H. from the Swiss National Science Foundation (SNF 32003B_172982/1). A.H. is a management committee member of COST action CA18211.

INSTUTIONAL REVIEW BOARD STATEMENT

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by Cantonal Ethics Committee of Vaud (study num-ber 2017-02142, approved on March 5th 2018).

INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in the study.

DATA AVAILABILITY STATEMENT

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to the lack of informed consent from participants for open access publication of their data.

ACKNOWLEDGEMENTS

The authors thank Ms Lara-Jessica Schütz, Dr Leah Gilbert, Ms Anna Favero, Ms Mathilde Duroux, Ms Yasmina Lofti, Ms Mélanie Hausser, Ms Annabelle Reuse, Ms Ava Cepleanu, Ms Cassie Pernet, Ms Daniela Barros Rodriguez, and Ms Camille Palombo for their precious help with data collection. The authors are grateful to Ms Sandrine Estoppey Younes, Pr Jardena Puder, and Pr David Baud for their logistical support, and the START Research Consortium (see Sandoz et al., 2019 for a full listing). Finally, our sincere thanks are addressed to the staff of the postpartum unit.

CONFILTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 5 ed. Arlington, VA: American Psychiatric Publishing; 2013.
2. Olde E, van der Hart O, Kleber R, van Son M. Posttraumatic stress following childbirth: a review. Clinical psychology review. 2006;26(1):1-16.
3. King L, McKenzie-McHarg K, Horsch A. Testing a cognitive model to predict posttraumatic stress disorder following childbirth. BMC pregnancy and childbirth. 2017;17(1):32.
4. Ehlert U, Gaab J, Heinrichs M. Psychoneuroendocrinological contributions to the etiology of depression, posttraumatic stress disorder, and stress-related bodily disorders: the role of the hypothalamus–pituitary–adrenal axis. Biological psychology. 2001;57:141-52.
5. Nagpal M, Gleichauf K, Ginsberg J. Meta-analysis of heart rate variability as a psychophysiological indicator of posttraumatic stress disorder. Trauma & Treatment. 2013;3(1):1000182.
6. Soet JE, Brack GA, Dilorio C. Prevalence and predictors of women's experience of psychological trauma during childbirth. Birth. 2003;30(1):36-46.
7. Ayers S. Delivery as a traumatic event: prevalence, risk factors, and treatment for postnatal posttraumatic stress disorder. Clinical obstetrics and Gynecology. 2004;47(3):552-67.
8. Slade P. Towards a conceptual framework for understanding post-traumatic stress symptoms following childbirth and implications for further research. Journal of Psychosomatic Obstetrics & Gynecology. 2006;27(2):99-105.
9. Horsch A, Garthus-Niegel S. Posttraumatic stress disorder following childbirth. In: Herring CPJ, editor. Childbirth, Vulnerability and Law: Exploring Issues of Violence and Control. 1st ed. London: Routledge; 2019. p. 49-66.
10. Zaers S, Waschke M, Ehlert U. Depressive symptoms and symptoms of post-traumatic stress disorder in women after childbirth. Journal of Psychosomatic Obstetrics & Gynecology. 2008;29 (1):61-71.
11. Ayers S, Bond R, Bertullies S, Wijma K. The aetiology of post-traumatic stress following childbirth: a meta-analysis and theoretical framework. Psychological Medicine. 2016;46(6):1121-34.
12. Grekin R, O'Hara MW. Prevalence and risk factors of postpartum posttraumatic stress disorder: a meta-analysis. Clinical psychology review. 2014;34(5):389-401.

13. Dikmen-Yildiz P, Ayers S, Phillips L. The prevalence of posttraumatic stress disorder in pregnancy and after birth: a systematic review and meta-analysis. Journal of affective disorders. 2017;208:634-47.

14. Ayers S, Harris R, Sawyer A, Parfitt Y, Ford E. Posttraumatic stress disorder after childbirth: analysis of symptom presentation and sampling. Journal of affective disorders. 2009;119(1-3):200-4.

15. Soderquist J, Wijma K, Wijma B. Traumatic Stress after Childbirth: The Role of Obstetric Variables. Journal of Psychosomatic Obstetrics & Gynecology. 2002;23(1):31-9.

16. van Heumen MA, Hollander MH, van Pampus MG, van Dillen J, Stramrood CAI. Psychosocial Predictors of Postpartum Posttraumatic Stress Disorder in Women With a Traumatic Childbirth Experience. Frontiers in Psychiatry. 2018;9(348).

17. Andersen LB, Melvaer LB, Videbech P, Lamont RF, Joergensen JS. Risk factors for developing posttraumatic stress disorder following childbirth: a systematic review. Acta obstetricia et gynecologica Scandinavica. 2012;91(11):1261-72.

18. Sandoz V, Deforges C, Stuijfzand S, Epiney M, Vial Y, Sekarski N, et al. Improving mental health and physiological stress responses in mothers following traumatic childbirth and in their infants: study protocol for the Swiss TrAumatic biRth Trial (START). BMJ Open. 2019;9(12):e032469.

19. Horesh D, Garthus-Niegel S, Horsch A. Childbirth-related PTSD: is it a unique post-traumatic disorder? Journal of Reproductive and Infant Psychology. 2021;39(3):221-4.

20. Garthus-Niegel S, Horsch A, Handtke E, von Soest T, Ayers S, Weidner K, et al. The impact of postpartum posttraumatic stress and depression symptoms on couples' relationship satisfaction: a population-based prospective study. Frontiers in Psychology. 2018;9:1728.

21. Delicate A, Ayers S, Easter A, McMullen S. The impact of childbirth-related post-traumatic stress on a couple's relationship: a systematic review and meta-synthesis. Journal of reproductive infant psychology. 2018;36(1):102-15.

22. Cook N, Ayers S, Horsch A. Maternal posttraumatic stress disorder during the perinatal period and child outcomes: a systematic review. Journal of affective disorders. 2018;225:18-31.

23. Garthus-Niegel S, Horsch A, von Soest T, Haga SM, Drozd F, Ayers S, et al. Posttraumatic stress symptoms following childbirth: associations with prenatal attachment in subsequent pregnancies. Archives of women's mental health. 2019;23(4):547-55.

24. Garthus-Niegel S, Ayers S, Martini J, Von Soest T, Eberhard-Gran M. The impact of postpartum post-traumatic stress disorder symptoms on child development: a population-based, 2-year follow-up study. Psychological medicine. 2017;47(1):161-70.

25. Garthus-Niegel S, Horsch A, Ayers S, Junge-Hoffmeister J, Weidner K, Eberhard-Gran M. The influence of postpartum PTSD on breastfeeding: a longitudinal population-based study. Birth. 2018;45(2):193-201.

26. Stuijfzand S, Garthus-Niegel S, Horsch A. Parental birth-related PTSD symptoms and bonding in the early postpartum period: a prospective population-based cohort study. Frontiers in psychiatry. 2020;11.

27. Bastos MH, Furuta M, Small R, McKenzie - McHarg K, Bick D. Debriefing interventions for the prevention of psychological trauma in women following childbirth. Cochrane Database of Systematic Reviews. 2015;CD007194(4).

28. Horsch A. Post traumatic stress disorder following childbirth and pregnancy loss. In: Beinard H, Kennedy P, S. L, editors. Clinical Psychology in Practice. Oxford: Blackwell, BPS; 2009. p. 274-87.

29. Del Giudice M, Ellis BJ, Shirtcliff EA. The Adaptive Calibration Model of stress responsivity. Neuroscience & Biobehavioral Reviews. 2011;35(7):1562-92.

30. Benfield RD, Newton ER, Tanner CJ, Heitkemper MM. Cortisol as a biomarker of stress in term human labor: physiological and methodological issues. Biological Research For Nursing. 2014;16(1):64-71.

31. Falk-Smith NL, Madrigal L. Maternal stress, anxiety, and fear of childbirth among planned homebirth mothers: results from a mixed methods study. The 88th Annual Meeting of the American Association of Physical Anthropologists; 27 March 2019; Cleveland, OH, USA2019. p. 71-2.

32. Miller N, Asali AA, Agassi-Zaitler M, Neumark E, Eisenberg MM, Hadi E, et al. Physiological and psychological stress responses to labor and delivery as expressed by salivary cortisol: a prospective study. American journal of obstetrics and gynecology. 2019;221(4):351.e1-.e7.

33. Meulenberg PM, Hofman JA. Differences between concentrations of salivary cortisol and cortisone and of free cortisol and cortisone in plasma during pregnancy and postpartum. Clinical chemistry. 1990;36(1):70-5.

34. Heinrichs M, Neumann I, Ehlert U. Lactation and stress: protective effects of breast-feeding in humans. Stress. 2002;5(3):195-203.

35. Pitman RK, Rasmusson AM, Koenen KC, Shin LM, Orr SP, Gilbertson MW, et al. Biological studies of post-traumatic stress disorder. Nature Reviews Neuroscience. 2012;13(11):769-87.

36. Miller GE, Chen E, Zhou ES. If it goes up, must it come down? Chronic stress and the hypothalamic-pituitary-adrenocortical axis in humans. Psychological bulletin. 2007;133(1):25-45.

37. England-Mason G, Kimber M, Khoury J, Atkinson L, MacMillan H, Gonzalez A. Difficulties with emotion regulation moderate the association between childhood history of maltreatment and cortisol reactivity to psychosocial challenge in postpartum women. Hormones and behavior. 2017;95:44-56.

38. Pierce ME, Pritchard LM. Lower stress-reactive cortisol in female veterans associated with military status but not PTSD. Stress. 2016;19(5):486-91.

39. Elzinga BM, Schmahl CG, Vermetten E, Van Dyck R, Bremner JD. Higher cortisol levels following exposure to traumatic reminders in abuse-related PTSD. Neuropsychopharmacology. 2003;28:1656-65.

40. Cordero MI, Moser DA, Manini A, Suardi F, Sancho-Rossignol A, Torrisi R, et al. Effects of interpersonal violence-related post-traumatic stress disorder (PTSD) on mother and child diurnal cortisol rhythm and cortisol reactivity to a laboratory stressor involving separation. Hormones and behavior. 2017;90:15-24.

41. Shaffer F, McCraty R, Zerr CL. A healthy heart is not a metronome: an integrative review of the heart's anatomy and heart rate variability. Frontiers in Psychology. 2014;5(1040).

42. Klinkenberg AV, Nater UM, Nierop A, Bratsikas A, Zimmermann R, Ehlert U. Heart rate variability changes in pregnant and non pregnant women during standardized psychosocial stress. Acta obstetricia et gynecologica Scandinavica. 2009;88(1):77-82.

43. Shaffer F, Ginsberg JP. An overview of heart rate variability metrics and norms. Frontiers in public health. 2017;5:258.

44. Finan PH, Zautra AJ, Wershba R. The dynamics of emotions in adaptation to stress. In: Contrada RJ, Baum A, editors. The Handbook of Stress Science: Biology, Psychology, and Health. New York: Springer Publishing Company; 2011. p. 209-20.

45. Kudielka BM, Hellhammer DH, Kirschbaum C. Ten years of research with the Trier Social Stress Test - revisited. In: Harmon-Jones E, P. Winkielman P, editors. Social neuroscience: Integrating biological and psychological explanations of social behavior. New York, NY: The Guilford Press; 2007. p. 56-83.

46. Dickerson SS, Kemeny ME. Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. Psychological bulletin. 2004;130(3):355-91.

47. Kirschbaum C, Pirke K-M, Hellhammer DH. The 'Trier Social Stress Test'–a tool for investigating psychobiological stress responses in a laboratory setting. Neuropsychobiology. 1993;28(1-2):76-81.

48. Ayers S, Crawley R, Webb R, Button S, Thornton A, the HABiT collaborative group. What are women stressed about after birth? Birth. 2019;46(4):678-85.

49. Bovin MJ, Marx BP, Weathers FW, Gallagher MW, Rodriguez P, Schnurr PP, et al. Psychometric properties of the PTSD checklist for diagnostic and statistical manual of mental disorders–fifth edition (PCL-5) in veterans. Psychological Assessment. 2016;28(11):1379-91.

50. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Annals of Internal Medicine. 2007;147(8):573-7.

51. Meyer T, Albrecht J, Bornschein G, Sachsse U, Herrmann-Lingen C. Posttraumatic Stress Disorder (PTSD) patients exhibit a blunted parasympathetic response to an emotional stressor. Applied Psychophysiology and Biofeedback. 2016;41(4):395-404.

52. Bouchet H, Plat A, Levréro F, Reby D, Patural H, Mathevon N. Baby cry recognition is independent of motherhood but improved by experience and exposure. Proceedings of the Royal Society B: Biological Sciences. 2020;287(1921):20192499.

53. Mason JW. A review of psychoendocrine research on the pituitary-adrenal cortical system. Psychosomatic medicine. 1968;30(5):576-607.

54. Bozovic D, Racic M, Ivkovic N. Salivary cortisol levels as a biological marker of stress reaction. Medical archives (Sarajevo, Bosnia and Herzegovina). 2013;67(5):374-7.

55. Hellhammer DH, Wust S, Kudielka BM. Salivary cortisol as a biomarker in stress research. Psychoneuroendocrinology. 2009;34(2):163-71.

56. Messerli-Bürgy N, Kakebeeke TH, Arhab A, Stülb K, Zysset AE, Leeger-Aschmann CS, et al. The Swiss Preschoolers' health study (SPLASHY): objectives and design of a prospective multi-site cohort study assessing psychological and physiological health in young children. BMC Pediatrics. 2016;16(1):1-16.

57. Schobinger E, Stuijfzand S, Horsch A. Acute and post-traumatic stress disorder symptoms in mothers and fathers following childbirth: a prospective cohort study. Frontiers in Psychiatry 2020;11(1502).

58. Cox JL, Holden JM, Sagovsky R. Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. The British journal of psychiatry. 1987;150(6):782-6.

59. Guedeney N, Fermanian J. Validation study of the French version of the Edinburgh Postnatal Depression Scale (EPDS): new results about use and psychometric properties. European psychiatry. 1998;13(2):83-9.

60. Horsch A, Tolsa J-F, Gilbert L, Jan Du Chêne L, Müller-Nix C, Bickle-Graz M. Improving maternal mental health following preterm birth using an expressive writing intervention: a randomized controlled trial. Child Psychiatry & Human Development. 2016;47(5):780-91.

61. Sandoz V, Bickle-Graz M, Camos V, Horsch A. Maternal postpartum depression symptoms are negatively associated with emotion regulation of children born very preterm. Acta paediatrica. 2019;108(5):969-70.

62. Zigmond AS, Snaith RP. The Hospital Anxiety and Depression Scale. Acta psychiatrica scandinavica. 1983;67(6):361-70.

63. Bocéréan C, Dupret E. A validation study of the Hospital Anxiety and Depression Scale (HADS) in a large sample of French employees. BMC Psychiatry. 2014;14(1):354.

64. Horsch A, Vial Y, Favrod C, Morisod Harari M, Blackwell SE, Watson P, et al. Reducing intrusive traumatic memories after emergency caesarean section: a proof-of-principle randomized controlled study. Behaviour research and therapy. 2017;94:36-47.

65. Allen AP, Kennedy PJ, Cryan JF, Dinan TG, Clarke G. Biological and psychological markers of stress in humans: focus on the Trier Social Stress Test. Neuroscience & Biobehavioral Reviews 2014;38:94-124.

66. R Development Core Team. R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2019.

67. Van Buuren S, Groothuis-Oudshoorn K. MICE: multivariate imputation by chained equations in R. Journal of statistical software. 2011;45(3):1-68.

68. Heinrichs M, Baumgartner T, Kirschbaum C, Ehlert U. Social support and oxytocin interact to suppress cortisol and subjective responses to psychosocial stress. Biological Psychiatry 2003;54(12):1389-98.

69. Wright KP, Drake AL, Frey DJ, Fleshner M, Desouza CA, Gronfier C, et al. Influence of sleep deprivation and circadian misalignment on cortisol, inflammatory markers, and cytokine balance. Brain, Behavior, and Immunity. 2015;47:24-34.

70. Almanza-Sepulveda ML, Fleming AS, Jonas W. Mothering revisited: A role for cortisol? Hormones and behavior. 2020;121:104679.

71. Lawrence RA, Lawrence RM. Physiology of lactation. In: Lawrence RA, Lawrence RM, editors. Breastfeeding (Seventh Edition). . Philadelphia: W.B. Saunders; 2011. p. 62-97.

72. Kaye J, Soothill P, Hunt M, Lightman S. Responses to the 35% CO challenge in postpartum women. Clin Endocrinol (Oxf). 2004;61(5):582-8.

73. Bauer AE, Wouk K, Grewen K, Gottfredson NC, Meltzer-Brody S, Propper C, et al. Associations of postpartum depression symptoms and infant feeding with Hypothalamic Pituitary Adrenal (HPA) axis reactivity. American journal of obstetrics and gynecology. 2020;222(1):S114.

74. Giles GE, Mahoney CR, Brunyé TT, Taylor HA, Kanarek RB. Stress effects on mood, HPA axis, and autonomic response: comparison of three psychosocial stress paradigms. PloS one. 2014;9(12):e113618-e.

75. Kudo N, Shinohara H, Kodama H. Heart rate variability biofeedback intervention for reduction of psychological stress during the early postpartum period. Applied Psychophysiology and Biofeedback. 2014;39(3-4):203-11.

76. Terkelsen AJ, Mølgaard H, Hansen J, Andersen OK, Jensen TS. Acute pain increases heart rate: Differential mechanisms during rest and mental stress. Autonomic Neuroscience. 2005;121(1):101-9.

77. Schechter DS, Moser DA, McCaw JE, Myers MM. Autonomic functioning in mothers with interpersonal violence related posttraumatic stress disorder in response to separation–reunion. Developmental Psychobiology. 2014;56(4):748-60.

78. Harrison SE, Ayers S, Quigley MA, Stein A, Alderdice F. Prevalence and factors associated with postpartum posttraumatic stress in a population-based maternity survey in England. Journal of affective disorders. 2020;279:749-56.

79. Ayers S, Wright DB, Thornton A. Development of a measure of postpartum PTSD: the City Birth Trauma Scale. Frontiers in psychiatry. 2018;9:409.

80. Sandoz V, Hingray C, Stuijfzand S, Lacroix A, El Hage W, Horsch A. Measurement and conceptualization of maternal PTSD following childbirth: Psychometric properties of the City Birth Trauma Scale – French version (City BiTS-F) Psychological Trauma: Theory, Research, Practice, and Policy. 2021.

81. Pruessner JC, Kirschbaum C, Meinlschmid G, Hellhammer DH. Two formulas for computation of the area under the curve represent measures of total hormone concentration versus time-dependent change. Psychoneuroendocrinology. 2003;28(7):916-31.

FIGURES AND TABLES

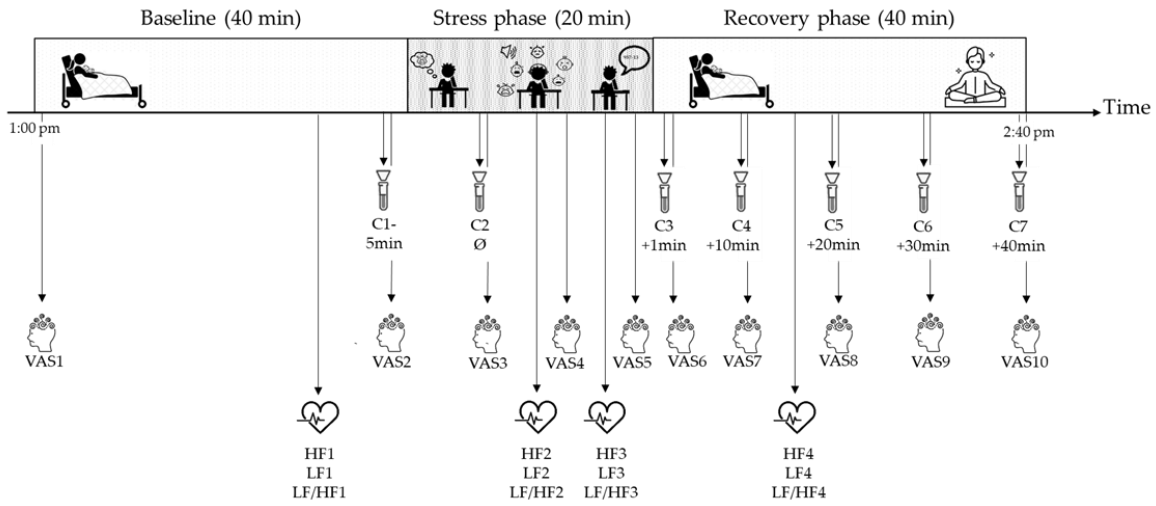


Figure 1. The procedure of the Lausanne Infant Crying Stress Paradigm contains a baseline phase and recovery phase, in which participants rest in their hospital room with their baby, as well as a stress phase, in which participants complete three stressful tasks (i.e., 3-min anticipation of the infant crying test, the infant crying test, and a surprise mental arithmetic task) in a consultation room. At the end of the recovery phase, an optional guided relaxation is offered to participants. Salivary cortisol assessments are represented by salivette icons, with the 1st salivary sample (C1) taken 5 min before the beginning of the stress phase, the 2nd salivary sample (C2) taken after the 3-min anticipation before the psychosocial and cognitive stressors, and the 3rd to 7th salivary samples (C3-C7) taken after the stress phase at 10 min interval. Perceived stress are illustrated with the head icon, measured 10 times via a visual analogous scale (VAS) ranging from 1 = *not at all stressed* to 5 = *extremely stressed*. Heart rate variability covering high-frequency (HF) power, low-frequency (LF) power, and LF/HF ratio is symbolized by the heart icon and is measured at four different time points.

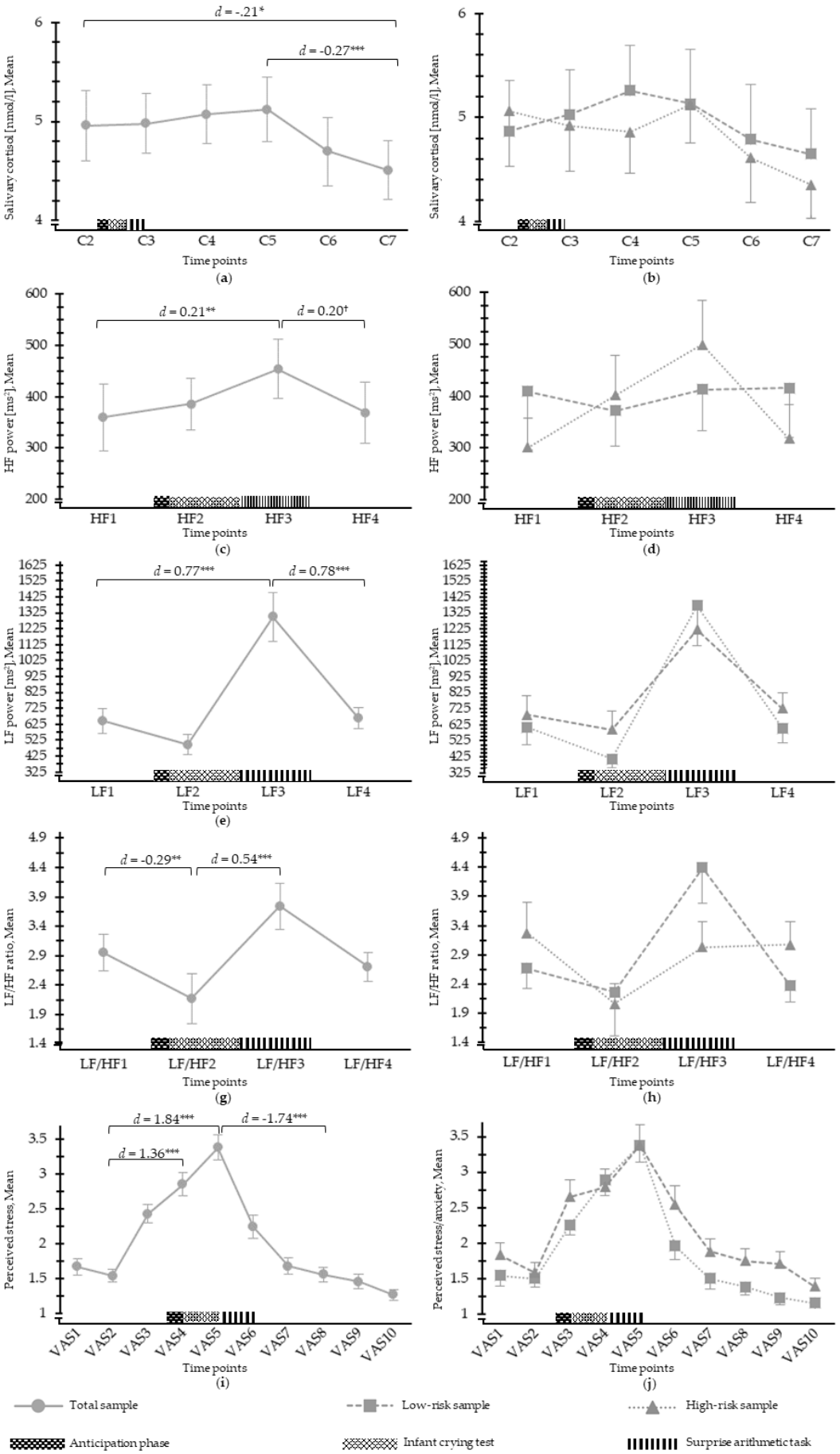

d = -.21*
d = -0.27***
Salivary cortisol [nmol/l], Mean
Time points
C2
C3
C4
C5
C6
C7
(a)
(b)
d = 0.21**
d = 0.20†
HF power [ms²], Mean
HF1
HF2
HF3
HF4
(c)
(d)
d = 0.77***
d = 0.78***
LF power [ms²], Mean
LF1
LF2
LF3
LF4
(e)
d = -0.29**
d = 0.54***
LF/HF ratio, Mean
LF/HF1
LF/HF2
LF/HF3
LF/HF4
(g)
(h)
d = 1.84***
d = -1.74***
d = 1.36***
Perceived stress, Mean
Perceived stress/anxiety, Mean
VAS1
VAS2
VAS3
VAS4
VAS5
VAS6
VAS7
VAS8
VAS9
VAS10
(i)
(j)
Total sample
Low-risk sample
High-risk sample
Anticipation phase
Infant crying test
Surprise arithmetic task

Figure 2. Mean psychophysiological stress reactivity during the different phases of the Lausanne Infant Crying Stress Paradigm: (**a**) mean salivary cortisol for the total sample; (**b**) mean salivary cortisol for the low- and high-risk groups; (**c**) mean HF power (HF, range: 0.15-0.4 ms^2) for the total sample; (**d**) mean HF power for the low- and high-risk groups; (**e**) mean LF power (LF, range: 0.04-0.15 ms^2) for the total sample; (**f**) mean LF power for the low- and high-risk groups; (**g**) mean LF/HF ratio for the total sample; (**h**) mean LF/HF ratio for the low- and high-risk groups; (**i**) mean perceived stress ratings (range: 1 = not at all – 5 = extremely) for the total sample; (**j**) mean perceived stress for the low- and high-risk groups. Error bars represent standard error. Graphs showing mean group stress response patterns over time are unadjusted and were displayed for illustrative purposes. When controlling for the perceived infant life threat, significant or marginal group effects on salivary cortisol release (d = 0.53*), HF power (d = 0.53†), LF/HF ratio (d = 0.93***), and perceived stress (d = 0.91***) emerged that are not indicated in this figure. $^{\dagger}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

- **Table 1.** Descriptive characteristics of the psychophysiological stress assessments

	Total sample (*n*=52)	Low-risk group (*n*=28)	High-risk group (*n*=24)
	M SD	*M SD*	*M SD*
Salivary cortisol [nmol/l]			
C1 level	5.5 (2.57)	5.31 (2.57)	5.72 (2.6)
C2 level	4.96 (2.19)	4.87 (2.27)	5.06 (2.15)
C3 level[1]	4.98 (2.13)	5.03 (2.31)	4.92 (1.96)
C4 level[1]	5.07 (2.35)	5.26 (2.79)	4.86 (1.79)
C5 level[1]	5.12 (2.47)	5.13 (2.8)	5.12 (2.12)
C6 level[1]	4.7 (2.13)	4.79 (2.29)	4.61 (1.98)
C7 level[1]	4.51 (2.19)	4.65 (2.51)	4.35 (1.82)
HF power [ms^2]			
HF1	359.56 (472.95)	409.07 (593.5)	301.79 (275.74)
HF2[2]	386.04 (364.14)	371.93 (363.87)	401.92 (371.61)
HF3[2, 3]	454.3 (417.7)	413.04 (421.67)	499.48 (418.85)
HF4[1]	369.2 (427.57)	416.19 (508.43)	318.29 (321.41)
LF power [ms^2]			
LF1	646.08 (572.69)	609.82 (574.26)	688.38 (580.22)
LF2[2]	497.08 (440.61)	410.44 (280.52)	594.54 (560.67)
LF3[2, 3]	1299.73 (1101.02)	1372.04 (1336.12)	1220.52 (793.71)
LF4[1]	663.36 (483.53)	602.81 (491.58)	728.96 (476.23)
LF/HF ratio			
LF/HF1	2.95 (2.22)	2.67 (1.81)	3.27 (2.62)
LF/HF2[2]	2.17 (3.09)	2.26 (3.96)	2.06 (1.72)
LF/HF3[2, 3]	3.74 (2.79)	4.39 (3.18)	3.03 (2.13)
LF/HF4[1]	2.71 (1.78)	2.38 (1.53)	3.07 (1.98)
Perceived stress			
VAS1	1.67 (0.83)	1.54 (0.79)	1.83 (0.87)
VAS2	1.54 (0.67)	1.5 (0.64)	1.58 (0.72)
VAS3	2.43 (0.96)	2.25 (0.7)	2.65 (1.18)
VAS4	2.85 (1.19)	2.89 (1.17)	2.79 (1.25)
VAS5[1]	3.38 (1.29)	3.38 (1.24)	3.38 (1.38)
VAS6[1]	2.24 (1.19)	1.96 (1.04)	2.54 (1.28)
VAS7[1]	1.68 (0.87)	1.5 (0.81)	1.88 (0.9)
VAS8[1]	1.56 (0.73)	1.38 (0.57)	1.75 (0.85)

VAS9[1]	1.46 (0.71)	1.23 (0.51)	1.71 (0.81)
VAS10[1]	1.27 (0.53)	1.15 (0.46)	1.39 (0.57)

Note. C1 = 1st salivary cortisol sample during the baseline; C2 = 2nd salivary cortisol sample taken before the psychosocial and cognitive stressors; C3 = 3rd salivary cortisol sample during recovery after the stress task; C4 = 4th salivary cortisol sample during early recovery; C5 = 5th salivary cortisol sample during mid recovery; C6 = 6th salivary cortisol sample during late recovery; C7 = 7th salivary cortisol sample during the recovery at the end of the paradigm; HF = high-frequency power; HF1 = HF during baseline; HF2 = HF during the psychosocial stressor; HF3 = HF during the cognitive stressor; HF4 = HF during the recovery; LF = low-frequency power; LF1 = LF during baseline; LF2 = LF during the psychosocial stressor; LF3 = LF during the cognitive stressor; LF4 = LF during the recovery; LF/HF1 = LF/HF ratio during baseline; LF/HF2 = LF/HF ratio during the psychosocial stressor; LF/HF3 = LF/HF ratio during the cognitive stressor; LF/HF4 = LF/HF ratio during the recovery; VAS = visual analogous scale ranging from 1 = not all stressed to 5 = extremely stressed; VAS1 = perceived stress at the beginning of the LICSP; VAS2 = perceived stress at C1; VAS3 = perceived stress at C2; VAS4 = perceived stress at the end of the ICT; VAS5 = perceived stress at the end of the math; VAS6 = perceived stress at C3; VAS7 = perceived stress at C4; VAS8 = perceived stress at C5; VAS9 = perceived stress at C6; VAS10 = perceived stress at C7. See Figure 1 for the detailed study procedure.

[1]Two participants of the low-risk group dropped at the of the stress phase, resulting in two missing data points

[2] Due to technical issues, the cardiac activity of one participant of the low-risk group was not recorded. Given > 30% of her data were missing, these data were not imputed.

[3] Seven participants ($n_{low\text{-}risk}$ = 4, $n_{high\text{-}risk}$ = 3) decided to stop the surprise arithmetic task before the recording of the 3-min cardiac activity.

- **Table 2.** Descriptive of the sample

	Total sample (*n*=52)	Low-risk group (*n*=28)	High-risk group (*n*=24)	Group difference
Sociodemographic and medical characteristics				
Age (*M, SD*)	31.71 (4.00)	33.48 (4.00)	31.83 (3.89)	*W* = 382.00, *p* = 0.276
Missing data (*N, %)*	1 (1.92)	1 (3.57)	0	
Civil status				*p* = 0.507
Married or in a relationship (*N, %*)	36 (69.23)	20 (71.43)	16 (66.67)	
Single, separated, divorced, or widowed (*N, %)*	7 (13.46)	3 (10.71)	4 (16.67)	
Others (*N*, %)	2 (3.87)	2 (7.14)	0	
Missing data (*N, %)*	7 (13.46)	3 (10.71)	4 (16.67)	
Education level				*p* = 0.407
Compulsory education (*N, %)*	3 (5.77)	2 (7.14)	1 (4.17)	
Post-compulsory education (*N, %*)		1 (3.57)	2	
Apprenticeship (*N, %)*	6 (11.54)	2 (7.14)	4 (16.67)	
University (*N, %)*	30 (57.69)	17 (60.71)	13 (54.17)	
Other (*N, %)*	3 (5.77)	3 (10.71)	0	
Missing data (*N, %)*	7 (13.46)	3 (10.71)	4 (16.67)	
Smoking				*p* = 0.242
Yes (*N*, %)	3 (5.77)	3 (10.71)	0	
No (*N*, %)	42 (80.77)	22 (78.58)	20 (83.33)	
Missing data (*N, %)*	7 (13.46)	3 (10.71)	4 (16.67)	
Parity (*M, SD*)	0.40 (0.72)	0.57 (0.74)	0.21 (0.66)	*W* = 436.00, *p* = 0.022
Gravidity (*M, SD*)	1.65 (1.25)	1.89 (1.23)	1.38 (1.24)	*W* = 450.00, *p* = 0.013
Type of delivery				*p* < 0.001
Vaginal birth (*N, %*)	28 (53.85)	22 (78.57)	6 (25.00)	
Planned caesarean section (*N, %)*	6 (11.54)	5 (17.86)	1 (4.17)	
Vacuum-assisted vaginal delivery (*N, %)*	1 (1.92)	0	1 (4.17)	

Forceps delivery (*N*, *%)*	3 (5.77)	0	3 (12.50)	
Emergency caesarean section (*N*, *%)*	14 (26.92)	1 (3.57)	13 (54.17)	
Psychological characteristics				
Perceived life threat for the mother (*M, SD*)	1.77 (1.63)	1.07 (0.26)	2.58 (2.13)	W = 211.00, p = 0.002
Perceived life threat for the infant (*M, SD*)	3.00 (2.22)	1.21 (0.42)	5.08 (1.53)	W = 6.00, p < 0.001
Anxiety, HADS-A (*M*, *SD)*	6.91 (3.65)	6.40 (3.25)	7.58 (4.1)	W = 198.50, p = 0.360
Cronbach's Alpha	0.72	0.68	0.76	
Missing data (*N*, *%)*	8 (15.38)	3 (10.71)	5 (20.83)	
Depression, EPDS (*M*, *SD)*	6.75 (5.13)	5.24 (3.75)	8.74 (6.06)	W = 155.00, p = 0.051
Cronbach's Alpha	1.77 (1.63)	1.07 (0.26)	2.58 (2.13)	W = 211.00, p = 0.002
Missing data (*N*, *%)*	3.00 (2.22)	1.21 (0.42)	5.08 (1.53)	W = 6.00, p < 0.001

Note. HADS-A = anxiety subscale of the Hospital Anxiety and Depression Scale (range = 0-21); EPDS = Edinburgh Postnatal Depression Scale (range = 0-30). Significant group differences were tested with Fischer's exact test (*p*), or Mann-Whitney test (W).

- **Table 3.** Descriptive data of the Lausanne Infant Crying Stress Paradigm

	Total sample (*n*=52)	Low-risk group (*n*=28)	High-risk group (*n*=24)	Group differences
Time between birth and the LICSP [hh:mm] (*M, SD*)	51:04 (22:02)	46:23 (21:50)	56:31 (21:27)	W = 236, p = 0.068
LICSP start time [hh:mm PM] (*M, SD*)	1:13 (0:20)	1:13 (0:20)	1:15 (0:20)	W = 309.5, p = 0.632
Baseline phase duration [mm:ss] (*M, SD*)	43:43 (3:28)	42:58 (2:45)	44:35 (4:01)	W = 256.5, p = 0.146
Stress phase duration [mm:ss] (*M, SD*)	21:41 (2:39)	21:58 (3:00)	21:23 (2:01)	W = 349, p = 643
Missing data (*N, %*)	1 (1.92)	1 (3.57)	0	
Recovery phase duration [mm:ss] (*M, SD*)	42:37 (4:28)	43:10 (5:53)	42:02 (2:02)	W = 341.5, p = 0.561
Missing data (*N, %*)	2 (3.85)	2 (7.14)	0	
LICSP duration [mm:ss] (*M, SD*)	107.68 (4.61)	107.38 (4.73)	108 (4.56)	W = 289.5, p = 0.668
Missing data (*N, %*)	2 (3.85)	2 (7.14)	0	
Breastfeeding within the hour preceding the stress phase				X2(1) = 0.06, p = 0.799
Yes (*N, %*)	9 (17.31)	4 (14.29)	5 (20.83)	
No (*N, %*)	43 (82.69)	24 (85.71)	19 (79.17)	
Characteristics of the stress phase				
Novelty (*M, SD*)	77.80 (28.34)	72.12 (29.91)	83.96 (25.75)	W = 220.5, p = 0.061
Missing data (*N, %*)	2 (3.85)	2 (7.14)	0	
Difficulty (*M, SD*)	63.96 (22.88)	65.31 (23.42)	62.50 (22.70)	W = 335, p = 0.66
Missing data (*N, %*)	2 (3.85)	2 (7.14)	0	
Stress (*M, SD*)	50.16 (27.09)	52.81 (24.61)	47.29 (29.82)	W = 345, p = 0.525
Missing data (*N, %*)	2 (3.85)	2 (7.14)	0	
Controllability (*M, SD*)	49.12 (29.19)	54.04 (33.32)	43.79 (23.48)	W = 376, p = 0.212
Missing data (*N, %*)	2 (3.85)	2 (7.14)	0	

Predictability (*M*, SD)	32.73 (29.23)	36.88 (27.22)	28.00 (31.36)	W = 303, p = 0.247
Missing data (*N*, *%*)	7 (13.46)	4 (14.29)	3 (12.50)	

Note. LICSP = Lausanne Infant Crying Stress Paradigm. Significant group differences were tested with Mann-Whitney (W) or Chi-square (X^2) tests. Characteristics of the stress phase were assessed on a 100-point Likert scale, with 0 = *not at all*, 50 = *moderately*, 100 = *extremely*.

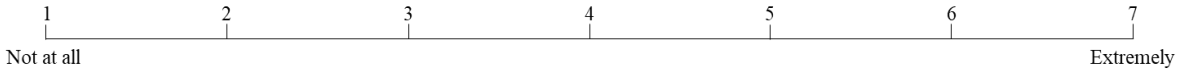
8.3. Appendix C

Instructions for the screening questions

Dear Madam,

The next four questions are about how you experienced and perceived your birth. I would like you to tell me the number that corresponds to your feeling/impression, knowing that 1 = not at all, and 7 = extremely. Don't get too hung up on what answer to give: your immediate reaction to each question will probably provide the best indication of how you feel, compared to a long thought-out answer. Also, when it comes to feelings, there are no right or wrong answers.

1. Did you think that your life was in danger?



2. Did you think that your baby's life was in danger?

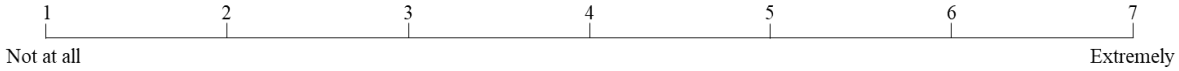


Table C.1. Group allocation based on the scoring of the screening questions

Group at low-risk of CB-PTSD	Group at high-risk of CB-PTSD	Not eligible
Scoring of :	If the scoring includes a response ≥ 4, such as example :	Scoring of :
1 – 1	1 – 4	2 – 2
1 – 2	1 – 7	2 – 3
2 – 1		3 – 2
		3 – 3

Note. CB-PTSD = childbirth-related post-traumatic stress disorder.

8.4. Appendix D

The distinct influence of different maternal mental health symptom profiles on infant sleep during the first year postpartum: a cross-sectional survey[5]

Vania Sandoz[1], Alain Lacroix[1], Suzannah Stuijfzand[1], Myriam Bickle Graz[2], and Antje Horsch[1,2*]

[1]Institute of Higher Education and Research in Healthcare, University of Lausanne, Switzerland. Vania.Sandoz@bluewin.ch

[2]Institute of Higher Education and Research in Healthcare, University of Lausanne, Switzerland. Alain.Lacroix@bluewin.ch

[3]Institute of Higher Education and Research in Healthcare, University of Lausanne, Switzerland. Suzannah.Stuijfzand@protonmail.com

[4]Department Woman-Mother-Child, Lausanne University Hospital, Switzerland. Myriam.Bickle-Graz@chuv.ch

[5]Institute of Higher Education and Research in Healthcare, University of Lausanne, Switzerland and Department Woman-Mother-Child, Lausanne University Hospital, Switzerland. Antje.Horsch@chuv.ch

Correspondence concerning this article should be addressed to Prof. Antje Horsch, Institute of Higher Education and Research in Healthcare, University of Lausanne, Biopôle 2, Route de la Corniche 10, 1010 Lausanne, Switzerland. Email: antje.horsch@chuv.ch

[5] Sandoz V, Lacroix A, Stuijfzand S, Bickle Graz M, horsch A. The distinct influence of different maternal mental health symptom profiles on infant sleep during the first year postpartum: a cross-sectional survey. Submitted to Early Human Development.

ABSTRACT

Background: The distinct influence of different, but comorbid, maternal mental health (MMH) difficulties (postpartum depression, anxiety, childbirth-related posttraumatic stress disorder) on infant sleep is unknown, although associations between MMH and infant sleep were reported.

Aims: 1. To examine associations between MMH symptoms and infant sleep; 2. To extract data-driven maternal MMH symptom profiles from MMH symptoms; 3. To investigate the distinct influence of these MMH symptom profiles on infant sleep, when including mediators and moderators.

Study design: cross-sectional study.

Subjects: French-speaking mothers of 3-12-month old infants (*n*=410).

Outcome measures: Standardized questionnaires assessed infant sleep (night waking and nocturnal sleep duration), method to fall asleep, maternal perception of infant negative emotionality (temperament dimension), and MMH symptoms. Sociodemographic data were also collected. Data was analyzed using 1. simple linear regressions; 2. factor analysis; and 3. structural equation modelling.

Results: 1. MMH symptoms were all negatively associated with nocturnal sleep duration. Only postpartum depression and anxiety symptoms were associated with night waking. 2. Three MMH symptom profiles were extracted: depressive, anxious, and birth trauma profiles. 3. The birth trauma profile (e.g., childbirth-related flashbacks) was not associated with infant sleep. Maternal perception of infant negative emotionality mediated the associations between the depressive or anxious profiles and infant sleep, but only for particular infant ages or maternal education levels. Associations between MMH symptom profiles and infant sleep were not mediated by the method to fall asleep.

Conclusions: The relationships between MMH and infant sleep may involve distinct mechanisms, contingent on maternal symptomatology.

Keywords*:* infant sleep, depression, PTSD, anxiety, birth trauma, mothers

HIGHLIGHTS

- Maternal depression or anxiety are linked to infant night waking or sleep duration.
- Maternal perception of infant temperament mediates these relationships.
- Links between childbirth-related PTSD and infant sleep are less evident.
- Method to fall asleep does not mediate any symptom profiles to infant sleep links.

INTRODUCTION

Infant sleep and maternal mental health

The prevalence of sleep problems during infancy is estimated to be between 10% and 17% (1, 2). Mothers typically reported short nocturnal sleep duration and/or night waking (1, 2). Focusing on sleep problems during infancy and childhood is important because they are negatively associated with maternal well-being (3, 4) and infant developmental outcomes (5). Interestingly, 69% of child insomnia does not have a physical cause, suggesting that it may be linked to parental behavior (6), e.g., nighttime parenting has been shown to be associated with infant night waking (3). Thus, several maternal nighttime behaviors may interfere with the infant's acquisition of self-regulation skills necessary to maintain sleep through the night or to self-soothe back to sleep (7). Associations between maternal nighttime parenting and maternal postpartum depression symptoms have also been reported (7).

Postpartum depression is common following childbirth, as are anxiety, and childbirth-related posttraumatic stress disorder (CB-PTSD) (8-12). Postpartum depression is characterized by a general state of low mood and/or anhedonia, and affects 13% of mothers during the first year postpartum (8, 9, 13). Anxiety involves worries, avoidance, obsessions, and physical changes, and its prevalence is up to 15% of mothers during the first six months postpartum (9, 10, 13). Finally, CB-PTSD develops after traumatic childbirth (i.e., perceived threat to the life of the mother and/or infant) and contains symptoms of re-experiencing, avoidance, negative cognitions and mood, and hyperarousal (13, 14). The prevalence of maternal CB-PTSD is estimated at 3-4% in low-risk samples and 16-19% in high-risk populations (11, 12).

Mounting evidence shows associations between maternal symptoms of postpartum depression or anxiety and the sleep of their offspring (3, 4, 15-17). However, regarding causal associations, findings of the few prospective studies are inconsistent, although recent results support mother-driven mechanisms in infancy (4, 15, 16). Moreover, the influence of maternal CB-PTSD symptoms on infant sleep during the first year postpartum has never been investigated, although maternal CB-PTSD symptoms at 8 weeks postpartum were shown to be prospectively linked to child sleep at 2 years postpartum (18).

The transactional model of infant sleep and parenting describes the interactions involved in infant sleep (7, 19). This model proposes that infant sleep shares complex and ongoing relationships with 1) the distal extrinsic context (e.g., maternal education), 2) the parenting factors context (e.g., maternal mental health), 3) intrinsic infant factors (e.g., infant age), and 4) the parent-infant interactive context, including interpersonal systems (e.g., maternal perception of infant temperament) and interactive behaviors factors (e.g., bedtime interactions) (7, 19). The evidence so far reported associations between infant sleep, perinatal maternal mental health symptoms (mainly depression), infant temperament (e.g., negative emotionality, often referred to as negative affectivity or negative temperament) and bedtime interactions (e.g., method to fall asleep), therefore supporting this theoretical framework (7, 20-23). Note that these studies diverge by their participants' age, variables of interest, study designs (e.g., cross sectional or longitudinal), as well as assessment tools and time points for their offspring sleep and maternal mental health. Importantly, findings on mechanisms underlying these associations are inconsistent and additional research

is therefore required, e.g., on the role of maternal perception of infant temperament in the relationships between maternal mental health and infant sleep.

Comorbidity of maternal mental health difficulties and their influence on infant sleep

Given the important comorbidity between maternal postpartum depression, anxiety, and CB-PTSD (13, 24-26), it raises the question of whether these mental health difficulties are distinct childbirth-related phenotypes. For example, in a recent cross-sectional study, postpartum depression and CB-PTSD symptoms loaded onto one-factor model explaining 68% of the total variance, when excluding the overlapping symptoms (i.e., anhedonia, sleep disturbance, and concentration difficulties) (24). Moreover, risk factors involved in comorbid postpartum depression and CB-PTSD were different from the ones associated with postpartum depression or CB-PTSD alone (24). Authors, therefore, suggested a specific posttraumatic stress-depressive profile that differs from postpartum depression or CB-PTSD (24).

The comorbidity between maternal mental health difficulties during the postpartum period also raises the question of how they interact together to influence infant sleep. To better understand the relationships between these postpartum disorders and infant sleep is important for both research and clinical practice. From a research point of view, if postpartum depression, anxiety, and CB-PTSD are associated with infant sleep via shared mechanisms, they could be investigated as one concept, whereas if distinct processes are involved, they would have to be considered separately. From a clinical point of view, this could have major implications on how families are cared for by perinatal health professionals, as mothers seldom experience symptoms of postpartum depression, anxiety, or CB-PTSD alone. To our knowledge, the shared influences of distinct mechanisms of postpartum depression, anxiety, and CB-PTSD contributing to deleterious effect on infant sleep have never been examined so far.

The current study

The first purpose of the current study was to examine the associations between maternal symptoms of postpartum depression, anxiety, or CB-PTSD and infant sleep (i.e., night waking and nocturnal sleep duration). Based on the literature, maternal mental health symptoms were expected to be positively associated with infant night waking, but negatively with nocturnal sleep duration (3, 18). Given that postpartum depression, anxiety, and CB-PTSD are comorbid (13, 24-26), the second aim consisted of extracting data-driven maternal mental health symptom profiles. Finally, the third aim was to investigate the distinct influence of these maternal mental health symptom profiles on infant sleep, when including mediators (i.e., the method to fall asleep and maternal perception of infant negative emotionality) and moderators (i.e., maternal education or infant age). The pathways to be tested were based on the transactional model of infant sleep and parenting (7, 19) (Figure 1).

[Insert Figure 1 - no color needed]

METHODS

Study design and population

This online cross-sectional study included 410 mother-infant dyads. Mothers and birth partners (i.e., male or female co-parent) first participated in a validation study and then completed an optional part assessing infant sleep and temperament. Details of the maternal validation study (n = 541) are reported elsewhere (27). Given that data collection for the birth partners is still ongoing, they will also be reported elsewhere. Therefore, the current paper only includes mothers who completed the two parts of the survey. Maternal eligibility criteria consisted of being the birth mother of an infant aged 3 to 12 months old, being ≥ 18 years old, and speaking French. For the 1.2% of participants who had twins, only data related to the first-born baby was used in the current study.

Infant and maternal measures

Brief Infant Sleep Questionnaire: This maternal-report questionnaire assessed various infant sleep variables over the previous week, such as nocturnal sleep duration (between 7pm to 7am), number of night waking, and method of falling asleep with the following response options: while being fed = 1, while being rocked = 2, while being held = 3, alone in the crib = 4, and in the crib with parental presence = 5 (28). A French translation and cultural adaptation was carried out according to the forward–backward method (29). This questionnaire demonstrated good psychometric properties (28).

Negative Emotionality dimension of the Very Short Form of the Infant Behavior Questionnaire-Revised (IBQ-NEG): This maternal-report questionnaire measured maternal perception of infant temperament, including the frequency of recent and concrete infant behaviors reported by mothers on a 7-point Likert scale (30). One of the three dimensions assessed by this maternal-report questionnaire is negative emotionality (IBQ-NEG). The IBQ-NEG 12-items indicate the tendency for the infant to express negative emotions, such as sadness, distress to limitation, and fear (30). The total score ranges from 1 to 7, with a higher score indicating higher negative emotionality (30). Given no validated French version exists, the forward-backward method was used for cultural adaptation and French translation (29). Good psychometric properties were reported for this questionnaire (30), and the IBQ-NEG internal consistency in this study was adequate (Cronbach's $\alpha = 0.82$).

Edinburgh Postnatal Depression Scale (EPDS): This 10-item self-report questionnaire assessed maternal postpartum depression symptoms within the last week (31). A higher total score (range: 0-40) indicates higher symptom severity (31). The French version of the EPDS showed good psychometric characteristics (32). In the current study, internal consistency was appropriate (Cronbach's $\alpha = 0.80$) and slightly lower than that previously reported in postpartum French-speaking mothers of Switzerland (33).

Anxiety Subscale of the Hospital Anxiety and Depression Scale (HADS-A): Anxiety symptoms occurring in the last week were assessed with the HADS-A (34). The total score of this 7-item self-report questionnaire ranges from 0 to 21, with higher scores suggesting higher symptom severity (34). Good psychometric properties have been reported in the French version (35). In the current study, Cronbach's α was good at 0.90, which was higher than what was previously reported in postpartum French-speaking mother of Switzerland (36).

City Birth Trauma Scale (City BiTS): The City BiTS is a self-report tool measuring the frequency of CB-PTSD symptoms over the last month (14). The City BiTS contains 29 items, with 20 of them evaluating PTSD symptom clusters of the Diagnostic and Statistical Manual of Mental Disorders, 5th ed (DSM-5; criteria B to E), namely intrusions, avoidance, negative cognitions and mood, and hyperarousal (13, 14). The City BiTS contains the birth-related symptoms subscale and the general symptoms subscales (14). The birth-related symptoms subscale is composed of items assessing symptoms of intrusion, avoidance, and a few that measure negative cognitions and mood. The general symptoms subscale consists of the rest of the items assessing negative cognitions and mood, and hyperarousal symptoms. Greater severity of CB-PTSD symptoms is suggested by a higher total score, which includes DSM-5 criteria B-E items (range: 0-60). The French version has demonstrated good psychometric properties (27). The Cronbach's α in the current study was good at 0.82, which was slightly lower than what was observed in postpartum English-speaking mothers (27).

Sociodemographic and medical data: The following information was collected via single items completed by the mothers: maternal age, marital status, and educational level (no education = 1, compulsory education = 2, post-compulsory education = 3, university of applied science or university diploma of technology degree = 4, and university =5), as well as weeks of gestation, and infant gender and age (≥3 months to <6 months = 1, ≥6 months to <9 months = 2, and ≥9 months to <12 months = 3).

Procedure

This online study was hosted on Sphinx iQ2, allowing data to be stored on a secure server owned by a Swiss university hospital. Data was collected between June and September 2020. The study was advertised mainly via social media, such as Facebook and Instagram, but also via personal and professional networks, and nurseries. Given that participants had to complete the last page of the survey for data to be saved, no information was available for early dropouts. The local ethics committee classified the study as anonymous, therefore not requiring full approval processing. Data are available free of charge and without restriction from the open access repository Zenodo (https://doi.org/10.5281/zenodo.5070945) (37).

Statistical analysis

Descriptive analyses and simple linear regressions were performed with IBM SPSS Statistics 27 (SPSS Inc., Chicago, IL, USA), while the rest of the analyses were carried out with R studio version 1.2.5033 and R version 3.6.2. Descriptive and exploratory analyses were conducted first to ensure that the data was appropriate for the planned analyses.

To detect relationships between maternal symptoms of postpartum depression, anxiety, or CB-PTSD symptoms and infant sleep (i.e., nocturnal sleep duration and night waking), six simple linear regressions were conducted. Maternal EPDS, HADS-A, or City BiTS score were used as predictors; infant nocturnal sleep duration or night waking were dependent variables.

To establish maternal mental health symptom profiles, an exploratory factor analysis with three predefined factors was conducted. The factor scores were computed as the sum of the items having a factor loading greater than

0.40. The main objective that drove this approach was the simplicity of interpretation of the computed scores. Cronbach's α was used to assess internal consistency. A confirmatory factor analysis was then conducted to assess the quality of the model. The following fit indices were used to evaluate the fit to the data: Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Standardized Root Mean Square Residual (SRMR). As a non-significant $\chi 2$ test, indicating a good fit, is rarely obtained with a large data set (38), we used the statistic adjusted by its degrees of freedom instead. RMSEA values below .06, CFI and TLI values above .95, and SRMR values below .08 indicate a good fit (39). It has then been suggested, with some consensus in the psychometric literature, that a model demonstrates reasonable fit if the value of $\chi 2/df$ does not exceed 3.0 (40). No outliers were detected.

Finally, to take into account the role of mediators (i.e., IBQ-NEG and method of falling asleep) and moderators (i.e., maternal educational level and infant age) in the associations between maternal mental health symptom profiles and infant sleep, we first recoded the educational level and method of falling asleep into dichotomous variables. Low educational level included responses *1*, *2*, and *3*, whereas high educational level comprised responses *4* and *5*. Regarding the method of falling asleep, responses *1,* 2*, 3*, and *5* were grouped as interactive method of falling asleep, while the non-interactive method of falling asleep only included response *4*. This choice was theory-driven, since infants who fall asleep with minimal parental involvement (e.g., alone in their crib) were reported to have better sleep outcomes (7). Mediation and moderation effects have been tested using structural equation modelling. To test for the significance of the indirect effects within the mediation models, bootstrapping with 1000 iterations was used.

Due to a technical issue, the response of one participant was missing for nocturnal sleep duration, which was not imputed. Results were considered as significant at $p < .05$.

RESULTS

Mothers were on average 30.20 years old (*SD* = 4.36), and most of them (94.9%) reported being in a couple relationship. Concerning infants, 51.7% were female and their age was, to a certain extent, equally distributed between categories (Table 1). Regarding the method to fall asleep, 56.8% children fell asleep with an interactive method, while a 43.2% required a non-interactive method of falling asleep. In addition, 31.7% mothers had a low educational level and 68.3% reported a high educational level. More information on the characteristics of the sample are displayed Table 1.

[Insert Table 1- no color needed]

Associations between maternal mental health symptoms and infant sleep problems

Associations between maternal mental health symptoms (i.e., total score of EPDS, HADS-A, and City BiTS) and infant sleep (i.e., night waking and nocturnal sleep duration) are shown in Table 2. All associations tested were significant, except for the association between City BiTS total score and night waking.

[Insert Table 2 - no color needed]

Maternal mental health symptom profiles

Loading values > 0.40 resulting from the exploratory factor analysis with 3 predefined factors are displayed in Table 3. The quality indices showed an acceptable fit to the data (*RMSEA* = 0.074, *CFI* = =.862, *TLI* = 0.851, $\chi 2/df$ = 3.238, *SRMR* = 0.056). Eight EPDS items, 2 HADS-A items, and 8 City BiTS items loaded on the first factor, which was named the *depressive profile*. Only 9 City BiTS items, all of which from the birth-related symptoms subscale, loaded on the second factor, entitled the *birth trauma profile*. Finally, 3 EPDS items, 4 HADS-A items, and 2 City BiTS items loaded on the third factor that was called the *anxious profile*. Item 11 of the HADS-A and items 8 and 18 of the City BiTS were included in neither of these three latent factors, since their loading values were < 0.40. The depressive profile was highly correlated with the anxious profile (r = 0.81, p < .001), but moderately with birth trauma profile (r = 0.41, p < .001). The anxious profile was also moderately correlated with the birth trauma profile (r = 0.46, p < .001).

[Insert Table 3 - no color needed]

Associations of maternal mental health symptom profiles to infant sleep problems

Out of the 24 moderated mediation models, five were significant (Table 4). Non-standardized beta coefficients are displayed in Figure 2. The association between the depressive profile and night waking was mediated by IBQ-NEG, whatever the infant age (model 1) or maternal education level (model 2). The association between the depressive profile and sleep night duration was also mediated via IBQ-NEG for infants aged 6 to 9 months (model 3). Finally, IBQ-NEG mediated the association between the anxious profile and night waking, but only when infant age was between 3 to 6 months (model 4) or maternal educational was high (model 5). Statistical information on the non-significant moderated mediation models is reported in Supplementary material.

[Insert Table 4 - no color needed]

[Insert Figure 2 - no color needed]

DISCUSSION

To our knowledge, this is the first study to explore the distinct effects of different, but comorbid, maternal mental health difficulties (postpartum depression, anxiety, and CB-PTSD) on infant sleep in the first year postpartum. Maternal postpartum depression and anxiety symptoms were associated with more night waking and less nocturnal sleep duration, as reported in previous studies (3, 4), whereas CB-PTSD symptoms were only associated with a shorter nocturnal sleep duration. When analyzing the EPDS, HADS-A, and City BiTS items, three mental health symptom profiles emerged, namely the depressive, the birth trauma, and the anxious profiles. The mothers' perception of infant negative temperament mediated several associations. Hence, maternal perception of infant negative emotionality mediated the association between the depressive profile and night waking, whatever the infant age (model 1) or maternal education (model 2); in 6-9 months old infants the association between depressive profile and nocturnal sleep duration (model 3); and finally, the association between the anxious profile and night waking when infants were 3 to 6 months old (model 4) or maternal education was high (model 5). We found no

mediating effect of infant temperament perception on the association between the birth trauma profile and infant sleep. Finally, the method to fall asleep did not mediate the influence of any of the maternal mental health symptom profiles on infant sleep problems, contrary to what was expected based on the transactional model of infant sleep and parenting (7).

In contrast to assumptions, maternal symptoms of CB-PTSD were not linked to infant night waking. One explanation may be that the infant may act as a reminder of the trauma, which could trigger re-experiencing symptoms (41, 42). As a result, mothers may experience infant-related avoidance (PTSD criteria C), and require their partner to care for the infant at night (41, 42). This is supported by findings demonstrating that mothers with CB-PTSD symptoms showed infant-directed hostility and diminished pleasure when interacting with their infant (41). Moreover, mothers with a likely CB-PTSD diagnosis showed less desire for proximity to their offspring (41). This assumption is speculative though, since partner involvement was not assessed in our study.

The unexpected lack of association between maternal CB-PTSD symptoms and night waking contrasts with the significant negative relationship observed between maternal CB-PTSD symptoms and nocturnal sleep duration. CB-PTSD-specific mechanisms associated with infant sleep may differ from the ones related to postpartum depression or anxiety. Given that CB-PTSD symptoms can impact maternal infant perception (41), mothers with CB-PTSD symptoms could have distorted beliefs concerning the expected night waking in infants, which might influence their reporting; however, this remains to be investigated. Since maternal CB-PTSD symptoms at 8 weeks postpartum prospectively predicted child sleep problems at two years postpartum (18), this suggests that the consequences of the intergenerational transmission of stress and trauma on infant sleep may develop after the first year postpartum.

Three profiles of mental health symptoms in mothers during the postpartum period emerged, namely the depressive, birth trauma, and anxious profiles. The depressive profile was characterized by symptoms linked to low mood, anhedonia, concentration problems, guilt, anger, irritability, social detachment, and self-destruction. The birth trauma profile covered symptoms including intrusive memories, avoidance, and negative mood and cognitions, all of which are related to childbirth. Finally, in the anxious profile symptoms of excessive worrying, infant-unrelated sleep difficulties, panic, and fear were present. Both the depressive and anxious profiles were composed of various symptoms of postpartum depression, anxiety, and CB-PTSD, while the birth trauma profile contained solely birth-related symptoms of CB-PTSD. In line with previous findings (24), this may suggest that these mental health difficulties are not totally distinct childbirth-related phenotypes. Given the important comorbidity of these disorders (13, 24-26), adopting a holistic approach and using maternal mental health symptom profiles can be of relevance for both clinical and research practice.

Three items of the City BiTS and HADS-A questionnaires did not contribute to the mental health profiles, which is relevant from a theoretical point of view. City BiTS item 8 relates to the difficulty of remembering the birth. Unlike other traumatic events, mothers usually experience childbirth with a birth partner, who can remind them about their experience. City BiTS item 18 refers to hypervigilance and HADS-A item 6 to feeling restless, and both could be seen as the norm when taking care of an infant.

Finally, an important aspect of the current study is the exploration of the distinct influence of the three profiles of maternal mental health symptoms on infant sleep problems. Both the associations between the depressive or anxious profiles and infant sleep were mediated by maternal perception of infant negative emotionality. Maternal symptoms of postpartum depression and anxiety have been shown to be associated with maternal perception of infant negative emotionality (43). Moreover, anxious or depressed mothers tended to report more difficult infant temperament, or to show more hostile feelings towards their infant and a more negative perception of their behavior in comparison with controls, respectively (44, 45). This negative perception of the infant may be linked to a behavior less attuned to their infant in depressed or anxious mothers, interfering with the acquisition of self-regulation skills (46). Thus, the associations between maternal depressive or anxiety symptoms and infant sleep may share common mechanisms, as illustrated by the high correlations observed between the depressive and anxious profiles.

It is important to note that the mediating effect in mothers with an anxious profile of the perception of negative infant temperament on night waking was only significant when maternal education was high or for infants aged 3 to 6 months old. A study showed that 4-months-old infants of mothers with a panic disorder woke up more often than controls (17). Their mothers were less sensitive with them and displayed parenting behaviors that may interfere with infant sleep (e.g., increased feeding at night) (17). The longest self-regulated sleep period (i.e., time of behavioral quietude with sleep and calm awakening) starts stabilizing around 4 months (47). It is therefore likely that infants aged between 3 to 6 months begin to sleep at night without manifesting distress, since they can self-soothe alone (47). In anxious mothers, who have a negative infant perception, hypervigilant behaviors towards their infant might develop as a response to this new sleep rhythm. For example, mothers, who are used to repeatedly waking up to help their infant fall back to sleep, may need to alleviate their anxiety by ensuring that their infant is healthy when they start sleeping through the night, which may inadvertently lead to maternal intrusive behavior (3). This intrusive maternal behavior may, in turn, impede infant sleep (4).

The finding related to maternal education was surprising. A higher educational level may give indications on the socioeconomic environment that is associated with parental cognitions and style, which are related to infant sleep (7). This remains to be explored in more detail in further studies.

Maternal perception of negative infant temperament mediated the association between the depressive profile and nocturnal sleep duration, but only for infants aged between 6 to 9 months. By the age of 6 months, infants are expected to sleep throughout the night (48). Teti and Crosby described behaviors in mothers with high depression symptoms who had concerns regarding infant needs at night that could result in infant waking (3). Authors proposed that mothers would engage in behaviors at night that would not aim to soothe their infant but rather to bring her closer to them (e.g., nursing them without sign of hunger, picking up their sleeping infant) (3). Their primary goal would then be to satisfy their own emotional needs (3). Furthermore, the possible cessation of breastfeeding occurring at this time (i.e., the rates of breastfeeding fall from 60% at 2 months postpartum, to 42% at 6 months postpartum, and 24% at 12 months postpartum (49)) might also explain this result, since breastfeeding is a soothing method (48). Thus, depressive mothers with a negative infant perception may struggle to soothe their infant with less than maximal maternal support (e.g., rocking their infant) (48), which, in turn, may interfere with the infant

acquiring self-regulation competencies (7). This hypothesis remains to be tested though.

Finally, it is interesting to note that the effect of the birth trauma profile on infant sleep was not mediated by the mother's perception of negative infant emotionality. Our findings, therefore, suggests that different maternal mental health symptoms influence infant sleep through distinct mechanisms. Recent results observed a lack of association between maternal birth-related symptoms of CB-PTSD and bonding, while general symptoms of CB-PTSD had a direct effect on bonding and an indirect effect via depressive symptoms (50). This suggests that the two dimensions of CB-PTSD, namely the birth-related symptoms and general symptoms, may have distinct influence on infant outcomes.

Strengths and limitations

This study addressed several gaps in the literature in perinatal research. To our knowledge, this is the first study to examine maternal CB-PTSD symptoms in relation to infant sleep. Secondly, this study considered the high comorbidity between the different maternal mental health difficulties, and explored for the first time the association between distinct maternal mental health symptom profiles and infant sleep. Third, the large sample size allowed the use of advanced analyses controlling for moderators and mediators, maximizing the potential insights that could be gained from the current study. Finally, the current study has important clinical and research implications. Our findings suggest that maternal negative perception of infant temperament must be considered in patients with infant sleep problems, as future infant sleep interventions could target this perception. From a research perspective, future studies should examine the mechanisms involved in the associations between maternal mental health symptom profiles, infant sleep, maternal perception of infant temperament, socioeconomic factors, and intrinsic infant factors.

Nonetheless, some limitations must be highlighted. First of all, information on current breastfeeding status, and partner involvement or mental health was not collected. The role of these variables in the relationship between maternal mental health and infant sleep could thus not be examined in the present analyses. Second, given the study design (i.e., online cross-sectional study), no physiological measure of sleep was collected and data were maternal-reported. This could have introduced a self-report bias although it has been reported that the number of infant night waking reported by mothers was not biased by maternal postpartum depression (3). Future research should therefore use objective measures (e.g., actigraphy, clinical interviews or behavioral assessment) not only in infants, but also in both parents during the pregnancy and postpartum period (7). This leads to the third limitation of this study, which was the lack of maternal mental health measurement during pregnancy. Indeed, antenatal maternal depression symptoms were prospectively associated with infant sleep (15). Thus, the current study would have benefitted from controlling for antenatal maternal mental health symptoms. Fourth, for statistical purposes, the method-to-fall-asleep variable was grouped into a dichotomous variable. Hence, the sensitivity of this measure may have been impacted while performing this statistical manipulation, which could potentially explain that the method to fall asleep did not mediate any relationships between maternal mental health symptom profile and infant sleep. Finally, no information was collected on the reasons for the choice of method to fall asleep used by mothers, nor on maternal cognitions linked to their parenting style during the night. Such information would definitively be interesting in future research to examine the influence of maternal mental health on infant sleep.

ACKNOWLEDGEMENTS

Authors would like to acknowledge Ms Yasmina Mabrouk for her help with data collection, as well as the women who shared their valuable time and took part in this study.

FUNDING

This study was supported by a project grant from the Swiss National Science Foundation (AH, grant number 32003B_172982). AH is a management committee member of COST action CA18211.

AUTHOR CONTRIBUTIONS

Conceptualization, VS, AH, SS, and MBG; Data curation, AL, and VS; Formal analysis, AL, VS, and AH; Funding acquisition, AH; Investigation, VS, and AH; Methodology, VS, AH, MBG, and SS; Project administration, VS and AH; Resources, AH; Software, AL and VS; Supervision, AH; Writing, VS, AH, MBG, and AL.

CONFLICT OF INTEREST

The authors have no conflict of interest to disclose related to this manuscript.

REFERENCES

1. Williamson AA, Mindell JA, Hiscock H, Quach J. Child sleep behaviors and sleep problems from infancy to school-age. Sleep Medicine. 2019;63:5-8.
2. Byars KC, Yolton K, Rausch J, Lanphear B, Beebe DW. Prevalence, patterns, and persistence of sleep problems in the first 3 years of life. Pediatrics. 2012;129(2):e276-84.
3. Teti DM, Crosby B. Maternal depressive symptoms, dysfunctional cognitions, and infant night waking: the role of maternal nighttime behavior. Child Development. 2012;83(3):939-53.
4. Cook F, Conway L, Gartland D, Giallo R, Keys E, Brown SA. Profiles and predictors of infant sleep problems across the first year. Journal of Developmental & Behavioral Pediatrics. 2020;41(2):104-16.
5. Spruyt K. A review of developmental consequences of poor sleep in childhood. Sleep Medicine. 2019;60:3-12.
6. Kahn A, Mozin MJ, Rebuffat E, Sottiaux M, Muller MF. Milk intolerance in children with persistent sleeplessness: a prospective double-blind crossover evaluation. Pediatrics. 1989;84(4):595-603.
7. Sadeh A, Tikotzky L, Scher A. Parenting and infant sleep. Sleep Med Rev. 2010;14(2):89-96.
8. Gavin NI, Gaynes BN, Lohr KN, Meltzer-Brody S, Gartlehner G, Swinson T. Perinatal depression: a systematic review of prevalence and incidence. Obstetrics & Gynecology. 2005;106(5 Part 1):1071-83.
9. O'Hara MW, Wisner KL. Perinatal mental illness: definition, description and aetiology. Best practice research Clinical obstetrics gynaecology. 2014;28(1):3-12.
10. Dennis C-L, Falah-Hassani K, Shiri R. Prevalence of antenatal and postnatal anxiety: systematic review and meta-analysis. The British Journal of Psychiatry. 2017;210(5):315-23.
11. Grekin R, O'Hara MW. Prevalence and risk factors of postpartum posttraumatic stress disorder: a meta-analysis. Clinical psychology review. 2014;34(5):389-401.
12. Dikmen-Yildiz P, Ayers S, Phillips L. The prevalence of posttraumatic stress disorder in pregnancy and after birth: a systematic review and meta-analysis. Journal of affective disorders. 2017;208:634-47.
13. American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 5 ed. Arlington, VA: American Psychiatric Publishing; 2013.
14. Ayers S, Wright DB, Thornton A. Development of a measure of postpartum PTSD: the City Birth Trauma Scale. Frontiers in psychiatry. 2018;9:409.

15. Dias CC, Figueiredo B. Mother's prenatal and postpartum depression symptoms and infant's sleep problems at 6 months. Infant Ment Health J. 2020;41(5):614-27.

16. Petzoldt J, Wittchen HU, Einsle F, Martini J. Maternal anxiety versus depressive disorders: specific relations to infants' crying, feeding and sleeping problems. Child Care Health Dev. 2016;42(2):231-45.

17. Warren SL, Gunnar MR, Kagan J, Anders TF, Simmens SJ, Rones M, et al. Maternal panic disorder: infant temperament, neurophysiology, and parenting behaviors. Journal of the American Academy of Child & Adolescent Psychiatry. 2003;42(7):814-25.

18. Garthus-Niegel S, Horsch A, Bickle Graz M, Martini J, von Soest T, Weidner K, et al. The prospective relationship between postpartum PTSD and child sleep: A 2-year follow-up study. Journal of affective disorders. 2018;241:71-9.

19. Sadeh A, Anders TF. Infant sleep problems: origins, assessment, interventions. Infant Ment Health J. 1993;14(1):17-34.

20. Parade SH, Wong K, Belair R, Dickstein S, Seifer R. Infant sleep moderates the effect of infant temperament on maternal depressive symptoms, maternal sensitivity, and family functioning. Infant Behavior and Development. 2019;57.

21. Field T. Infant sleep problems and interventions: a review. Infant Behavior and Development. 2017;47:40-53.

22. Morrell J, Steele H. The role of attachment security, temperament, maternal perception, and care-giving behavior in persistent infant sleeping problems. Infant Mental Health Journal. 2003;24(5):447-68.

23. Burdayron R, Butler BP, Béliveau M-J, Dubois-Comtois K, Pennestri M-H. Perception of infant sleep problems: the role of negative affectivity and maternal depression. Journal of clinical sleep medicine. 2021;17(6):1279-85.

24. Dekel S, Ein-Dor T, Dishy GA, Mayopoulos PA. Beyond postpartum depression: posttraumatic stress-depressive response following childbirth. Archives of Women's Mental Health. 2020;23(4):557-64.

25. Dikmen-Yildiz P, Ayers S, Phillips L. Depression, anxiety, PTSD and comorbidity in perinatal women in Turkey: a longitudinal population-based study. Midwifery. 2017;55:29-37.

26. Agius A, Xuereb RB, Carrick-Sen D, Sultana R, Rankin J. The co-existence of depression, anxiety and post-traumatic stress symptoms in the perinatal period: a systematic review. Midwifery. 2016;36:70-9.

27. Sandoz V, Hingray C, Stuijfzand S, Lacroix A, El Hage W, Horsch A. Measurement and conceptualization of maternal PTSD following childbirth: psychometric properties of the City Birth Trauma Scale – French version (City BiTS-F). Psychological Trauma: Theory, Research, Practice, and Policy. 2021.

28. Sadeh A. A brief screening questionnaire for infant sleep problems: validation and findings for an Internet sample. Pediatrics. 2004;113(6):e570-e7.

29. Wild D, Grove A, Martin M, Eremenco S, McElroy S, Verjee-Lorenz A, et al. Principles of Good Practice for the Translation and Cultural Adaptation Process for Patient-Reported Outcomes (PRO) Measures: report of the ISPOR Task Force for Translation and Cultural Adaptation. Value in health. 2005;8(2):94-104.

30. Putnam SP, Helbig AL, Gartstein MA, Rothbart MK, Leerkes E. Development and Assessment of Short and Very Short Forms of the Infant Behavior Questionnaire–Revised. Journal of Personality Assessment. 2014;96(4):445-58.

31. Cox JL, Holden JM, Sagovsky R. Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. The British journal of psychiatry. 1987;150(6):782-6.

32. Guedeney N, Fermanian J. Validation study of the French version of the Edinburgh Postnatal Depression Scale (EPDS): new results about use and psychometric properties. European psychiatry. 1998;13(2):83-9.

33. Sandoz V, Stuijfzand S, Lacroix A, Deforges C, Quillet Diop M, Ehlert U, et al. The Lausanne Infant Crying Stress Paradigm: validation of an early postpartum stress paradigm with women at low- vs. high-risk of childbirth-related posttraumatic stress disorder. J Pers Med. 2021;11(6):472.

34. Zigmond AS, Snaith RP. The Hospital Anxiety and Depression Scale. Acta psychiatrica scandinavica. 1983;67(6):361-70.

35. Bocéréan C, Dupret E. A validation study of the Hospital Anxiety and Depression Scale (HADS) in a large sample of French employees. BMC Psychiatry. 2014;14(1):354.

36. Horsch A, Vial Y, Favrod C, Morisod Harari M, Blackwell SE, Watson P, et al. Reducing intrusive traumatic memories after emergency caesarean section: a proof-of-principle randomized controlled study. Behaviour research and therapy. 2017;94:36-47.

37. Sandoz V, Horsch A. Dataset of The distinct influence of different maternal mental health symptom profiles on infant sleep during the first year postpartum: a cross-sectional survey. 2021.

38. Barrett P. Structural equation modelling: Adjudging model fit. Personality and Individual differences. 2007;42(5):815-24.

39. Hu L, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling: A Multidisciplinary Journal. 1999;6(1):1-55.

40. Kline RB. Principles and practice of structural equation modeling. 4 ed: Guilford publications; 2015.

41. Davies J, Slade P, Wright I, Stewart P. Posttraumatic stress symptoms following childbirth and mothers' perceptions of their infants. Infant Ment Health J. 2008;29(6):537-54.

42. Harrison SE, Ayers S, Quigley MA, Stein A, Alderdice F. Prevalence and factors associated with postpartum posttraumatic stress in a population-based maternity survey in England. Journal of affective disorders. 2020;279:749-56.

43. Sechi C, Vismara L, Rollè L, Prino LE, Lucarelli L. First-Time Mothers' and Fathers' Developmental Changes in the Perception of Their Daughters' and Sons' Temperament: Its Association With Parents' Mental Health. Front Psychol. 2020;11.

44. Cornish AM, McMahon CA, Ungerer JA, Barnett B, Kowalenko N, Tennant C. Maternal depression and the experience of parenting in the second postnatal year. Journal of Reproductive and Infant Psychology. 2006;24(2):121-32.

45. McMahon C, Barnett B, Kowalenko N, Tennant C, Don N. Postnatal Depression, Anxiety and Unsettled Infant Behaviour. Australian & New Zealand Journal of Psychiatry. 2001;35(5):581-8.

46. Sadeh A, Flint-Ofir E, Tirosh T, Tikotzky L. Infant sleep and parental sleep-related cognitions. Journal of family psychology : JFP : journal of the Division of Family Psychology of the American Psychological Association (Division 43). 2007;21(1):74-87.

47. Henderson JMT, France KG, Blampied NM. The consolidation of infants' nocturnal sleep across the first year of life. Sleep Medicine Reviews. 2011;15(4):211-20.

48. Thirion M, Challamel M-J. Le sommeil, le rêve et l'enfant. Paris, France: Albin Michel; 2011.

49. Magarey A, Kavian F, Scott JA, Markow K, Daniels L. Feeding mode of Australian infants in the first 12 months of life: an assessment against national breastfeeding indicators. Journal of Human Lactation. 2015;32(4):NP95-NP104.

50. Nakić Radoš S, Matijaš M, Anđelinović M, Čartolovni A, Ayers S. The role of posttraumatic stress and depression symptoms in mother-infant bonding. Journal of affective disorders. 2020;268:134-40.

Table 1. Descriptive Characteristics of the Sample

	Participants (n = 410)	
	M (SD)	n (%)
Maternal age	30.20 (4.36)	
Educational level		
No education		2 (0.5)
Compulsory education		25 (6.1)
Post-compulsory education (e.g., apprenticeship)		103 (25.1)
University of Applied Science or University Diploma of Technology Degree		88 (21.5)
University		192 (46.8)
Marital status		
Single		14 (3.4)
In a couple relationship		389 (94.9)
Separated, divorced, or widowed		7 (1.7)
EPDS total score	9.05 (6.76)	
HADS-A total score	7.84 (4.26)	
City BiTS total score	13.12 (10.81)	
Infant gender		
Female		212 (51.7)
Male		198 (48.3)
Weeks of gestation	39.11 (1.90)	
Infant age		
≥3 months to <6 months		147 (35.9)
≥6 months to <9 months		133 (32.4)
≥9 months to <12 months		130 (31.7)
Nocturnal sleep duration (min)	611.04 (85.985)	

Missing data		1 (0.2)
Night waking	1.44 (1.59)	
Method to fall asleep		
While being fed		90 (22)
While being rocked		74 (18)
While being held		22 (5.4)
Alone in the crib		177 (43.2)
In the crib with parental presence		47 (11.5)
IBQ-NEG	3.36 (1.10)	

Note. City BiTS = City Birth Trauma Scale; EPDS = Edinburgh Postnatal Depression Scale; HADS-A = Anxiety subscale of the Hospital Anxiety and Depression Scale; IBQ-NEG = Negative Emotionality dimension of the Very Short Form of the Infant Behavior Questionnaire-Revised

Table 2. Simple Linear Regression Models

Model	Predictor	Dependent variable	*n*	*β*	R^2	*F*	*p*
1	EPDS	Night waking	410	0.03	0.019	8.08	.005
2	EPDS	Nocturnal sleep duration	409	-2.51	0.039	16.54	< .001
3	HADS-A	Night waking	410	0.04	0.011	4.49	.035
4	HADS-A	Nocturnal sleep duration	409	-2.59	0.016	6.77	.010
5	City BiTS	Night waking	410	0.01	0.004	1.60	.207
6	City BiTS	Nocturnal sleep duration	409	-0.80	0.010	4.17	.042

Note. EPDS = Edinburgh Postnatal Depression Scale; HADS-A = anxiety subscale of the Hospital Anxiety and Depression Scale; City BiTS = City Birth Trauma Scale.

Table 3. Exploratory factor analysis with three predefined factors (n = 410)

Items	Depressive profile	Birth trauma profile	Anxious profile
EPDS			
1. Being able to laugh and see the funny side of things.	0.70		
2. Looking forward with enjoyment to things.	0.62		
3. Blaming oneself unnecessarily when things went wrong.	0.51		
4. Being anxious or worried for no good reason.			0.65
5. Feeling scared or panicky for no very good reason.			0.66
6. Things have been getting on top of oneself.	0.53		
7. Being so unhappy that one's have had difficulty sleeping.	0.51		0.44
8. Feeling sad or miserable.	0.70		
9. Being so unhappy that one's have been crying.	0.65		
10. The thought of harming oneself has occurred.	0.49		
HADS-A			
1. Feeling tense or angry.	0.64		
2. Feeling scared like something might happen to oneself.			0.64
3. Worrying.			0.66

4. Sitting restfully doing nothing and feeling calm.	0.41		
5. Feeling scared and having knots in one's stomach.			0.64
6. Feeling restless and finding it difficult to stay in place.			
7. Often feeling panicky.			0.71
City BiTS: birth-related symptoms			
1. Recurrent unwanted memories of the birth…		0.71	
2. Bad dreams or nightmares about the birth …		0.49	
3. Flashbacks to the birth and/or reliving the experience.		0.49	
4. Getting upset when reminded of the birth.		0.79	
5. Feeling tense or anxious when reminded of the birth.		0.80	
6. Trying to avoid thinking about the birth.		0.77	
7. Trying to avoid things that remind me of the birth …		0.70	
8. Not able to remember details of the birth.			
9. Blaming myself or others for what happened during the birth.		0.62	
10. Feeling strong negative emotions about the birth.		0.70	
City BiTS: General symptoms			
11. Feeling negative about myself or thinking something awful will happen.	0.45		0.48

12. Lost interest in activities that were important to me.	0.65		
13. Feeling detached from other people-	0.69		
14. Not able to feel positive emotions …	0.70		
15. Feeling irritable or aggressive.	0.74		
16. Feeling self-destructive or acting recklessly.	0.50		
17. Feeling tense and on edge.	0.73		
18. Feeling jumpy or easily startled.			
19. Problems concentrating.	0.60		
20. Not sleeping well … not due to the baby's sleep pattern.			0.45
Cronbach α, 95% CI	0.94, [0.93, 0.95]	0.87, [0.87, 0.90]	0.91, [0.89, 0.92]

Note. Only loading values > 0.40 are reported. City BiTS = City Birth Trauma Scale – French Version; EPDS = Edinburgh Postnatal Depression Scale; HADS-A = anxiety subscale of the Hospital Anxiety and Depression Scale.

Table 4. Significant moderated mediation models investigating relationships between maternal mental health symptom profiles and infant sleep

Independent variable	Dependent variable	Mediator	Covariate	Moderator	*ACME*, *95% CI*	*p*
Model 1						
Depressive profile	Night waking	IBQ-NEG	Method to fall asleep	Infant age: ≥3 months to <6 months	0.013, [0.006, 0.024]	<.001
Depressive profile	Night waking	IBQ-NEG	Method to fall asleep	Infant age: ≥6 months to <9 months	0.006, [0.001, 0.014]	.02
Depressive profile	Night waking	IBQ-NEG	Method to fall asleep	Infant age: ≥9 months to <12 months	0.009, [0.001, 0.024]	.028
Model 2						
Depressive profile	Night waking	IBQ-NEG	Method to fall asleep	Low educational level	0.007, [0.002, 0.015]	.004
Depressive profile	Night waking	IBQ-NEG	Method to fall asleep	High educational level	0.009, [0.004, 0.017]	<.001
Model 3						
Depressive profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	Infant age: ≥6 months to <9 months	-0.296, [-0.677, -0.067]	.012
Model 4						
Anxious profile	Night waking	IBQ-NEG	Method to fall asleep	Infant age: ≥3 months to <6 months	0.013, [0.004, 0.026]	<.001
Model 5						
Anxious profile	Night waking	IBQ-NEG	Method to fall asleep	High educational level	0.009, [0.001, 0.021]	.032

Note. ACME = average causal mediation effect; IBQ-NEG = negative emotionality subscale of the Very Short Form of the Infant Behavior Questionnaire-Revised. Non-significant moderated mediation models are not reported here.

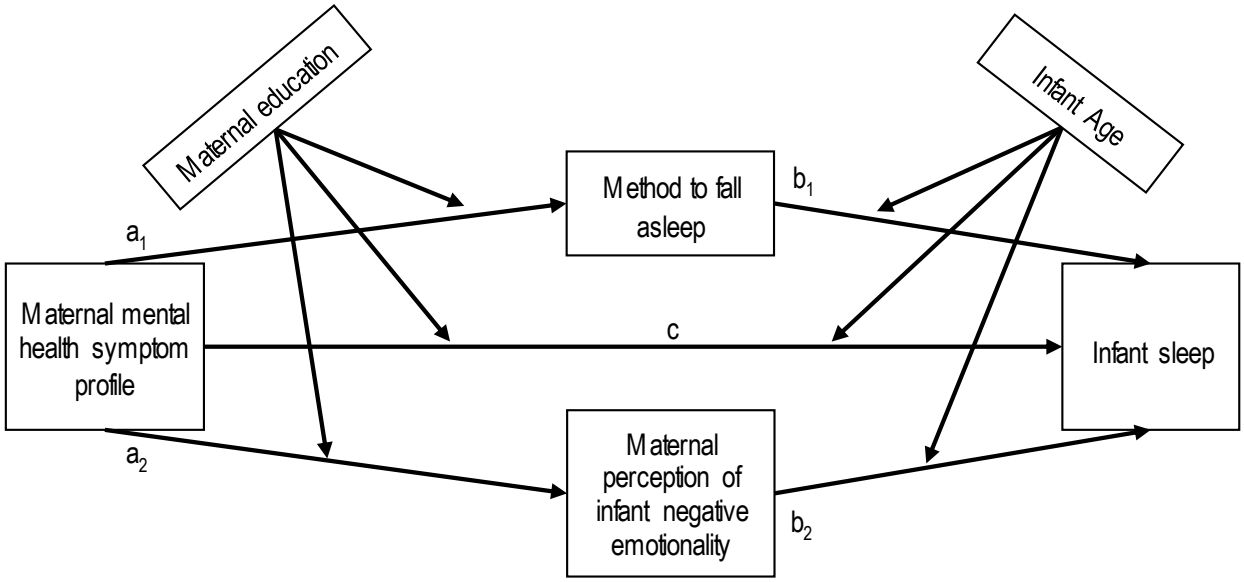


Figure 1. Tested pathways playing a role in the association between a maternal mental health symptom profile and an infant sleep outcome.

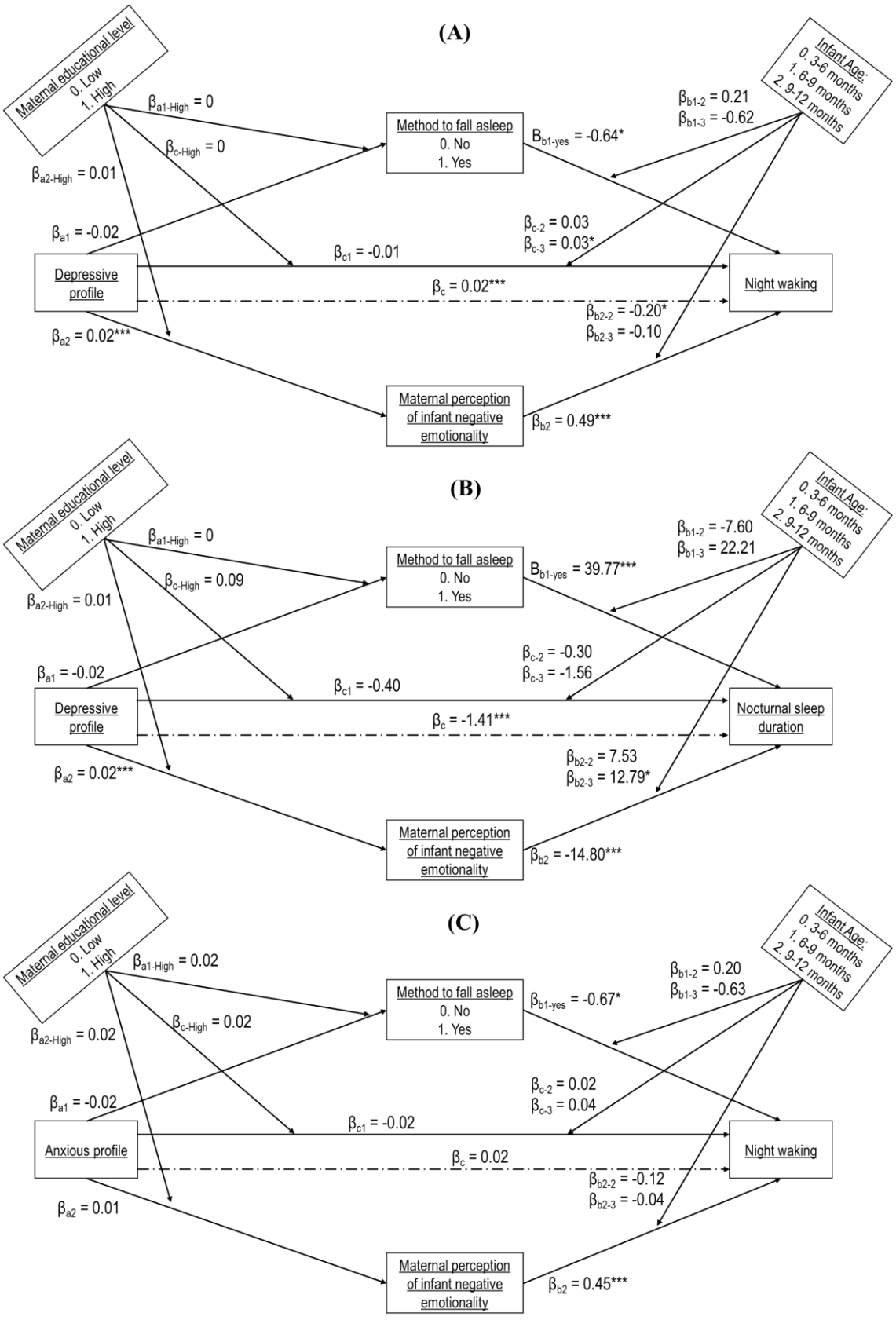


Figure 2. Model A displays the path model of the effect of the depressive profile on night waking, including mediators and moderators. Model B presents the path model of the effect of nocturnal sleep duration by the depressive profile, taking into account mediators and moderators. Model C represents the path model of the effect

of the anxious profile on night waking, including mediators and moderators. Maternal perception of infant negative emotionality and the method to fall asleep are tested as mediators for all models, as well as maternal educational level and infant age as moderators. Dashed lines show the direct associations between the maternal mental health symptom profiles and infant sleep indicators, without including the other factors in the model. Non standardized beta coefficients are reported. *p < .05; ***p < .001.

8.5. Appendix E

Statement of the ethics committee of Vaud on the fact that Study 3 not requiring a full approval process

Sandoz Vania

De: swissethics <messaging@basec.swissethics.ch>
Envoyé: mardi 9 juin 2020 10:18
À: Sandoz Vania
Objet: Req-2020-00688 : Votre question à la CER-VD

Please do not reply below this line

Please note that when replying to this message, all other recipients mentioned below will receive your message.

Other recipients: Zinn-Poget, Arthur

Project: Bonjour,
Nous souhaitons réaliser une enquête anonyme visant les parents ayant récemment accouché (càd il y a plus d'un mois, mais moins de 12 mois) et parlant français. Ainsi, les participant.e.s proviendront de toute la francophonie. Avons-nous besoin (Req-2020-00688)
Form: Clarification of responsibility / Support Request
Consult the whole conversation

Message:

Bonjour,

Après analyse de votre demande, la CER-VD estime que si:

a) le recrutement est fait via un lien dans réseau sociaux/annonces ou remise d'une information contenant un lien sans garder de trace de la remise du document;

b) le logiciel n'enregistre pas l'IP;

c) l'accès aux données collectées est fait au terme de la période de récolte (après 1000 réponses)

alors il est raisonnable de considérer que le questionnaire est anonyme et que partant, le projet n'entre pass dans le champ d'application de la LRH et ne nécessite pas d'autorisation de la CER-VD pour être menée.

Nous attirons cependant votre attention sur le fait que l'anonymat des données a un caractère relatif et qu'il est nécessaire de prendre les mesures afin de prévenir toute tentative de ré-identification par croisement de données.

Avec nos meilleures salutations,

Arthur Zinn-Poget
Secrétaire général
Commission cantonale d'éthique de la recherche sur l'être humain
Av. de Chailly 23
1012 Lausanne
021 316 18 31

Lu/Ma/Me/Je

Informations importantes: les personnes mentionnées ci-dessus et/ou figurant en copie du document annexé reçoivent une copie de ce message. En cas de réponse par l'un des récipiendaires, une copie sera

[Numéro de page]

8.6. Appendix F

Table F.1. Non-significant moderated mediation models investigating relationships between maternal mental health symptom profiles and infant sleep.

Independent variable	Dependent variable	Mediator	Covariate	Moderator	*ACME*, *95% CI*	*p*
Model 3						
Depressive profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	Infant age: ≥3 months to <6 months	-0.249, [-0.737, 0.239]	.292
Depressive profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	Infant age: ≥9 months to <12 months	-0.047, [-0.439, 0.177]	.768
Model 4						
Anxious profile	Night waking	IBQ-NEG	Method to fall asleep	Infant age: ≥6 months to <9 months	0.003, [-0.005, 0.014]	.524
Anxious profile	Night waking	IBQ-NEG	Method to fall asleep	Infant age: ≥9 months to <12 months	0.009, [-0.003, 0.026]	.236
Model 5						
Anxious profile	Night waking	IBQ-NEG	Method to fall asleep	Low educational level	0.009, [0, 0.021]	.072
Model 6						
Depressive profile	Night waking	Method to fall asleep	IBQ-NEG	Low educational level	0.005, [0, 0.013]	.1
Depressive profile	Night waking	Method to fall asleep	IBQ-NEG	High educational level	0.003 [0, 0.007]	.08
Model 7						
Depressive profile	Nocturnal sleep duration	Method to fall asleep	IBQ-NEG	Low educational level	-0.226, [-0.772, 0]	.108
Depressive profile	Nocturnal sleep duration	Method to fall asleep	IBQ-NEG	High educational level	-0.242. [-0.548, 0.012]	.076

Model 8						
Depressive profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	Low educational level	-0.217, [-0.681, 0.107]	.324
Depressive profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	High educational level	-0.058, [-0.359, 0.14]	.572
Model 9						
Birth trauma profile	Night waking	Method to fall asleep	IBQ-NEG	Low educational level	0.007, [-0.004, 0.022]	.248
Birth trauma profile	Night waking	Method to fall asleep	IBQ-NEG	High educational level	-0.009, [-0.019, 0]	.064
Model 10						
Birth trauma profile	Night waking	IBQ-NEG	Method to fall asleep	Low educational level	0.001, [-0.012, 0.014]	.872
Birth trauma profile	Night waking	IBQ-NEG	Method to fall asleep	High educational level	0.002, [-0.009, 0.013]	.732
Model 11						
Birth trauma profile	Nocturnal sleep duration	Method to fall asleep	IBQ-NEG	Low educational level	-0.361, [-1.263, 0.207]	.3
Birth trauma profile	Nocturnal sleep duration	Method to fall asleep	IBQ-NEG	High educational level	0.668, [-0.012, 1.455]	.064
Model 12						
Birth trauma profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	Low educational level	-0.033, [-0.69, 0.275]	.872
Birth trauma profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	High educational level	-0.021, [-0.355, 0.076]	.78
Model 13						
Anxious profile	Night waking	Method to fall asleep	IBQ-NEG	Low educational level	0.01, [0.001, 0.025]	.06

Anxious profile	Night waking	Method to fall asleep	IBQ-NEG	High educational level	-0.001, [-0.007, 0.006]	.848
Model 14						
Anxious profile	Nocturnal sleep duration	Method to fall asleep	IBQ-NEG	Low educational level	-0.489, [-1.394, -0.015]	.068
Anxious profile	Nocturnal sleep duration	Method to fall asleep	IBQ-NEG	High educational level	0.042, [-0.434, 0.582]	.896
Model 15						
Anxious profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	Low educational level	-0.237, [-1.152, 0.06]	.284
Anxious profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	High educational level	-0.08, [-0.334, 0.107]	.38
Model 16						
Depressive profile	Night waking	Method to fall asleep	IBQ-NEG	Infant age: ≥3 months to <6 months	0.001, [-0.004, 0.006]	.648
Depressive profile	Night waking	Method to fall asleep	IBQ-NEG	Infant age: ≥6 months to <9 months	0.004, [0, 0.012]	.052
Depressive profile	Night waking	Method to fall asleep	IBQ-NEG	Infant age: ≥9 months to <12 months	0.005, [-0.003, 0.014]	.292
Model 17						
Depressive profile	Nocturnal sleep duration	Method to fall asleep	IBQ-NEG	Infant age: ≥3 months to <6 months	-0.071, [-0.459, 0.199]	.596
Depressive profile	Nocturnal sleep duration	Method to fall asleep	IBQ-NEG	Infant age: ≥6 months to <9 months	-0.177, [-0.609, 0.019]	.152
Depressive profile	Nocturnal sleep duration	Method to fall asleep	IBQ-NEG	Infant age: ≥9 months to <12 months	-0.245, [-0.681, 0.164]	.24
Model 18						
Birth trauma profile	Night waking	Method to fall asleep	IBQ-NEG	Infant age: ≥3 months to <6 months	-0.001, [-0.015, 0.008]	.828

Birth trauma profile	Night waking	Method to fall asleep	IBQ-NEG	Infant age: ≥6 months to <9 months	-0.003, [-0.015, 0.003]	.408
Birth trauma profile	Night waking	Method to fall asleep	IBQ-NEG	Infant age: ≥9 months to <12 months	-0.001, [-0.023, 0.018]	.924
Model 19						
Birth trauma profile	Night waking	IBQ-NEG	Method to fall asleep	Infant age: ≥3 months to <6 months	0.006, [-0.005, 0.021]	.376
Birth trauma profile	Night waking	IBQ-NEG	Method to fall asleep	Infant age: ≥6 months to <9 months	0.003, [-0.006, 0.017]	.628
Birth trauma profile	Night waking	IBQ-NEG	Method to fall asleep	Infant age: ≥9 months to <12 months	-0.009, [-0.046, 0.009]	.236
Model 20						
Birth trauma profile	Nocturnal sleep duration	Method to fall asleep	IBQ-NEG	Infant age: ≥3 months to <6 months	0.08, [-0.481, 0.838]	.872
Birth trauma profile	Nocturnal sleep duration	Method to fall asleep	IBQ-NEG	Infant age: ≥6 months to <9 months	0.153, [-0.141, 0.671]	.36
Birth trauma profile	Nocturnal sleep duration	Method to fall asleep	IBQ-NEG	Infant age: ≥9 months to <12 months	0.048, [-0.956, 1.091]	.892
Model 21						
Birth trauma profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	Infant age: ≥3 months to <6 months	-0.158, [-0.733, 0.131]	.476
Birth trauma profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	Infant age: ≥6 months to <9 months	-0.155, [-0.968, 0.314]	.608
Birth trauma profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	Infant age: ≥9 months to <12 months	0.12, [-0.243, 0.599]	.656
Model 22						
Anxious profile	Night waking	Method to fall asleep	IBQ-NEG	Infant age: ≥3 months to <6 months	0.003, [-0.005, 0.012]	.42
Anxious profile	Night waking	Method to fall asleep	IBQ-NEG	Infant age: ≥6 months to <9 months	-0.003, [-0.002, 0.012]	.312

Anxious profile	Night waking	Method to fall asleep	IBQ-NEG	Infant age: ≥9 months to <12 months	0, [-0.015, 0.016]	.94
Model 23						
Anxious profile	Nocturnal sleep duration	Method to fall asleep	IBQ-NEG	Infant age: ≥3 months to <6 months	-0.174, [-0.946, 0.232]	.544
Anxious profile	Nocturnal sleep duration	Method to fall asleep	IBQ-NEG	Infant age: ≥6 months to <9 months	0.151, [-0.719, 0.114]	.368
Anxious profile	Nocturnal sleep duration	Method to fall asleep	IBQ-NEG	Infant age: ≥9 months to <12 months	0.003, [-0.796, 0.874]	.924
Model 24						
Anxious profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	Infant age: ≥3 months to <6 months	-0.283, [-1.052, 0.14]	.284
Anxious profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	Infant age: ≥6 months to <9 months	-0.172, [-0.822, 0.28]	.504
Anxious profile	Nocturnal sleep duration	IBQ-NEG	Method to fall asleep	Infant age: ≥9 months to <12 months	-0.081, [-0.707, 0.081]	.58

Note. IBQ-NEG = negative emotionality subscale of the Very Short Form of the Infant Behavior Questionnaire-Revised.

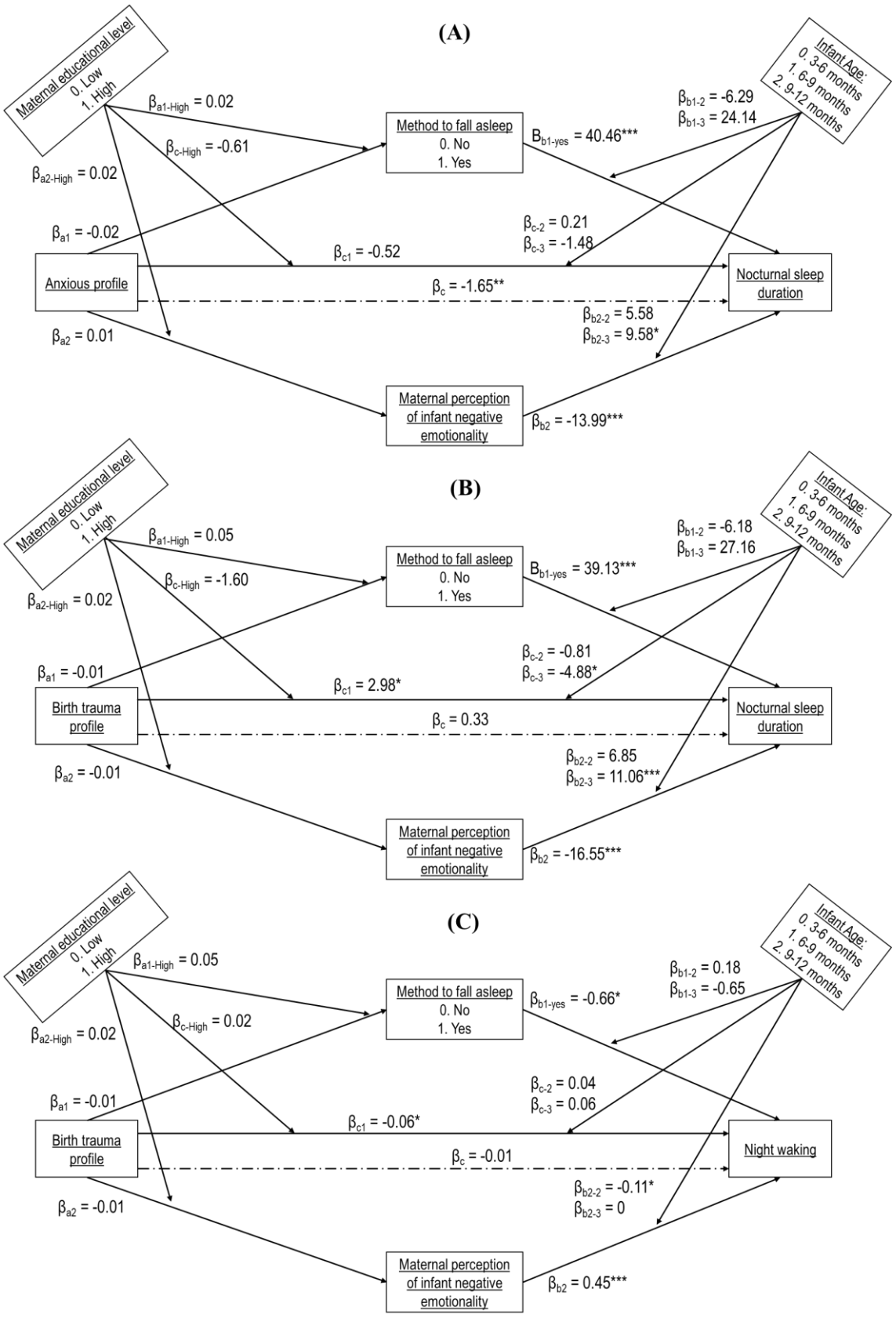


Figure F.1. Model A displays the path model of the influence of the anxious profile on nocturnal sleep duration, including mediators and moderators. Model B presents the path model of the prediction of nocturnal sleep duration

by birth trauma profile, taking into account mediators and moderators. Model C represents the path model of the influence of the birth trauma profile on night waking, including mediators and moderators. Maternal perception of infant negative emotionality and the method to fall asleep are tested as mediators for all models, as well as maternal educational level and infant age as moderators. Dashed lines show the direct association between the maternal mental health symptom profile and infant sleep without including the other factors in the model. Non standardized beta coefficients are reported. *p < .05; **p < .001; ***p < .001.

8.7. Appendix G

Table G.1. Team co-supervising

Status	Duration	Work percentage
Graduated psychologist	6 months	40%
Graduated psychologist	6 months	80%
Graduated psychologist	6 months	50%
Psychology student	10 months	50%
Psychology student	9 months	50%
Psychology student	1 year	50%
Psychology student	1 year	50%
Psychology student	6 months	50%
Psychology student	1 year	45%
Psychology student	1 year	35%
Psychology student	6 months	30%
Psychology student	6 months	20%
Psychology student	3 months	100%
Psychology student	2 months	50%
Psychology student	1 year	50%
Psychology student	1 year	50%
Nursing student	1 year	50%

Note. The co-supervisions were jointly carried out with Ms Camille Deforges and Prof. Antje Horsch.

Table G.2. Master thesis supervision

Name of the student	Master thesis project
Sebara Gashi, (nursing sciences student)	Title: Subjective birth perception: comparison of perception between parents, midwives and obstetricians. Publications: two publications are planned for 2021-2022, in which I will be conjointly last-author with Prof. Horsch.
Anna Favero, (psychology student)	Title: The impact of maternal and paternal socio-demographic & prenatal mental health factors on neonatal outcomes. Publication: a publication is planned for 2021, in which I will be first author.
Mathilde Duroux, (psychology student)	Title: Investigating prenatal perceived support as a protective factor against adverse birth outcomes. Publication: the manuscript is currently under reviewed, and I am co-author.

Table G.3. Public and scientific engagements during my PhD

Events	Description
Le Fou de Normandie in 2021	Intervention on the mental health of birth partners during the perinatal period on a YouTube channel to promote the participation of partners in the French validation study of the City Birth Trauma Scale – partner version.
2020-2021 Interdisciplinary Academy for Early Childhood Researchers of the Swiss Society for Early Childhood Research	Conjointly with juniors and seniors researchers, I was actively involved in the establishment, organisation, and running of this academy destined to early career researchers of Switzerland.
2019, 2020, and 2021 workshops of the Society for Reproductive and Infant Psychology for early career researchers	Conjointly with others juniors researchers, I was actively involved in the establishment, organisation, and running of several international workshops for early career researchers from 2019 to 2021.
2019 Swiss Perinatal Research Day	I was volunteer during a one-day conference at Lausanne, Switzerland.
2019 World Prematurity Day	I participated in this event, which aimed to raise awareness about perinatal mental health after a preterm birth at Lausanne, Switzerland.
2018 Annual meeting of the toy libraries of the Cantons of Vaud and Valais	I presented a popularised oral presentation on the prevention of the post-traumatic stress disorder with Tetris.

Table G.4. National and international conferences during my PhD

Authors, title, date, conferences, and location	Type of presentation
Sandoz V*, Stuijfzand S, Messerli-Bürgy N, Deforges C, Quillet Diop M, Ehlert U, et al. The Lausanne Infant Crying Stress Paradigm: Development and validation of an Early Postpartum Stress Paradigm within birth-related traumatised vs nontraumatised women. 2nd Annual meeting of the Swiss Society for Early Childhood Research. 2020. Online	Oral presentation
Sandoz V*, Messerli-Bürgy N, Deforges C, Stuijfzand S, Sekarski N, Ehlert U, et al. Development and validation of the Lausanne Infant Crying Stress Paradigm: A stress paradigm for the early postpartum period. 2nd Annual meeting of the Swiss Society for Early Childhood Research. 2019. Lausanne, Switzerland.	Poster presentation
Deforges C*, **Sandoz V,** Stuijfzand S, Porcheret K, Horsch A. Impact of sleep after a traumatic childbirth on posttraumatic symptom development: a prospective study. 2nd Annual meeting of the Swiss Society for Early Childhood Research. 2019. Lausanne, Switzerland.	Flash presentation
Stuijfzand S*, **Sandoz V,** Deforges C, Morisod Harari M, Horsch A. START Project: The effect of postpartum PTSD on mother-child interaction. 2nd Annual meeting of the Swiss Society for Early Childhood Research. 2019. Lausanne, Switzerland.	Poster presentation
Gashi S*, Stuijfzand S, Horsch A†, **Sandoz V†** (†joint authors). Traumatic Childbirth: Comparison of the subjective perception of parents, midwives and obstetricians. A mixed study. 2nd Annual meeting of the Swiss Society for Early Childhood Research. 2019. Lausanne, Switzerland.	Poster presentation
Duroux M*, Stuijfzand S, **Sandoz V,** Horsch A. Investigating prenatal social support as a protective factor: Does it moderate the relationship between prenatal anxiety and birth outcomes? 2nd Annual meeting of the Swiss Society for Early Childhood Research. 2019. Lausanne, Switzerland.	Poster presentation
Favero A*, **Sandoz V,** Stuijfzand S, Horsch A. Moving beyond antenatal maternal mental health: Considering the role of antenatal paternal mental health in predicting adverse neonatal outcomes. 2nd Annual meeting of the Swiss Society for Early Childhood Research. 2019. Lausanne, Switzerland.	Poster presentation
Sandoz V*, Deforges C, Stuijfzand S, Epiney M, Vial Y, Sekarski N, et al. Improving mental health and physiological stress responses in mothers following traumatic childbirth and in their infants: a randomized controlled trial. 39th Annual Conference of the Society for Reproductive and Infant Psychology. 2019. London, UK.	Oral presentation
Sandoz V*, Messerli-Bürgy N, Deforges C, Stuijfzand S, Sekarski N, Ehlert U, et al. The Lausanne Infant Crying Stress Paradigm: Development and validation of an early postpartum	Oral presentation

stress paradigm within birth-related traumatised vs non-traumatised women. 39th Annual Conference of the Society for Reproductive and Infant Psychology. 2019. London, UK.	
Deforges C*, **Sandoz V,** Stuijfzand S, Porcheret K, Horsch A. Impact of sleep after a traumatic childbirth on posttraumatic symptom development: a prospective study. 39th Annual Conference of the Society for Reproductive and Infant Psychology. 2019. London, UK.	Oral presentation
Sandoz V*, Bickle-Graz M, Camos V, Horsch A. Impact of maternal postpartum depression and posttraumatic stress symptoms on emotion regulation of preschoolers born very preterm: a prospective study. The Swiss Perinatal Research Day. 2019. Lausanne, Switzerland.	Oral presentation
Deforges C*, **Sandoz V,** Stuijfzand S, Porcheret K, Horsch A. Impact of sleep after a traumatic childbirth on posttraumatic symptom development: a prospective study. The Swiss Perinatal Research Day. 2019. Lausanne, Switzerland.	Oral presentation
Gashi S*, Stuijfzand S, Horsch A, Vial Y, Dessauve D, **Sandoz V.** Traumatic Childbirth: Comparison of the subjective perception of parents, midwives and obstetricians. A mixed-method study. The Swiss Perinatal Research Day. 2019. Lausanne, Switzerland.	Poster presentation
Sandoz V*, Messerli-Bürgy N, Deforges C, Stuijfzand S, Sekarski N, Ehlert U, et al. The Lausanne Infant Crying Stress Paradigm: Development and validation of an early postpartum stress paradigm within birth-related traumatised vs non-traumatised women. The Doctoral Day of the Faculty of Biology and Medicine of the University of Lausanne. 2019. Lausanne, Switzerland.	Poster presentation
Sandoz V*, Messerli-Bürgy N, Sekarski N, Ehlert U, Deforges C, Stuijfzand S, et al. Maternal and Infant Stress Physiology in the Early Postpartum Period. The Stressnetwork.ch. 2019. Basel, Switzerland.	Poster presentation
Stuijfzand S*, **Sandoz V,** Deforges C, Harari Morisod M, Horsch A, on behalf of the START Research Consortium. START Project: the effect of postpartum PTSD on mother-child interaction. The Stressnetwork.ch. 2019. Basel, Switzerland.	Poster presentation
Sandoz V*, Bickle-Graz M, Camos V, Horsch A. Impact of maternal postpartum depression and posttraumatic stress symptoms on emotion regulation of preschoolers born very preterm: a prospective study. The 38th Annual SRIP Conference. 2018. Lodz, Poland.	Oral presentation
Sandoz V*, Bickle-Graz M, Camos V, Horsch A. Impact of maternal postpartum depression and posttraumatic stress symptoms on emotion regulation of preschoolers born very preterm: a prospective study. The 2018 French Marcé Society Congress. 2018. Lyon, France.	Oral presentation
Sandoz V*, Bickle-Graz M, Camos V, Horsch A. Impact of maternal postpartum depression and posttraumatic stress symptoms on emotion regulation of preschoolers born very preterm: a prospective study. The fPmh congress. 2018. Lausanne, Switzerland.	Oral presentation

Sandoz V*, Bickle-Graz M, Camos V, Horsch A. Impact of maternal postpartum depression and posttraumatic stress symptoms on emotion regulation of preschoolers born very preterm: a prospective study. Journée de recherché en pédiatrie. 2018. Lausanne, Switzerland.	Oral presentation

Note.* = the person who presented the work at the conference.

Table G.5. Awards won during my PhD.

Awards	**Organisation**
2021 public prize of *Ma thèse en 180 secondes*	University of Lausanne
Laureate of the Students 2019 Bursary	Society for Reproductive and Infant Psychology