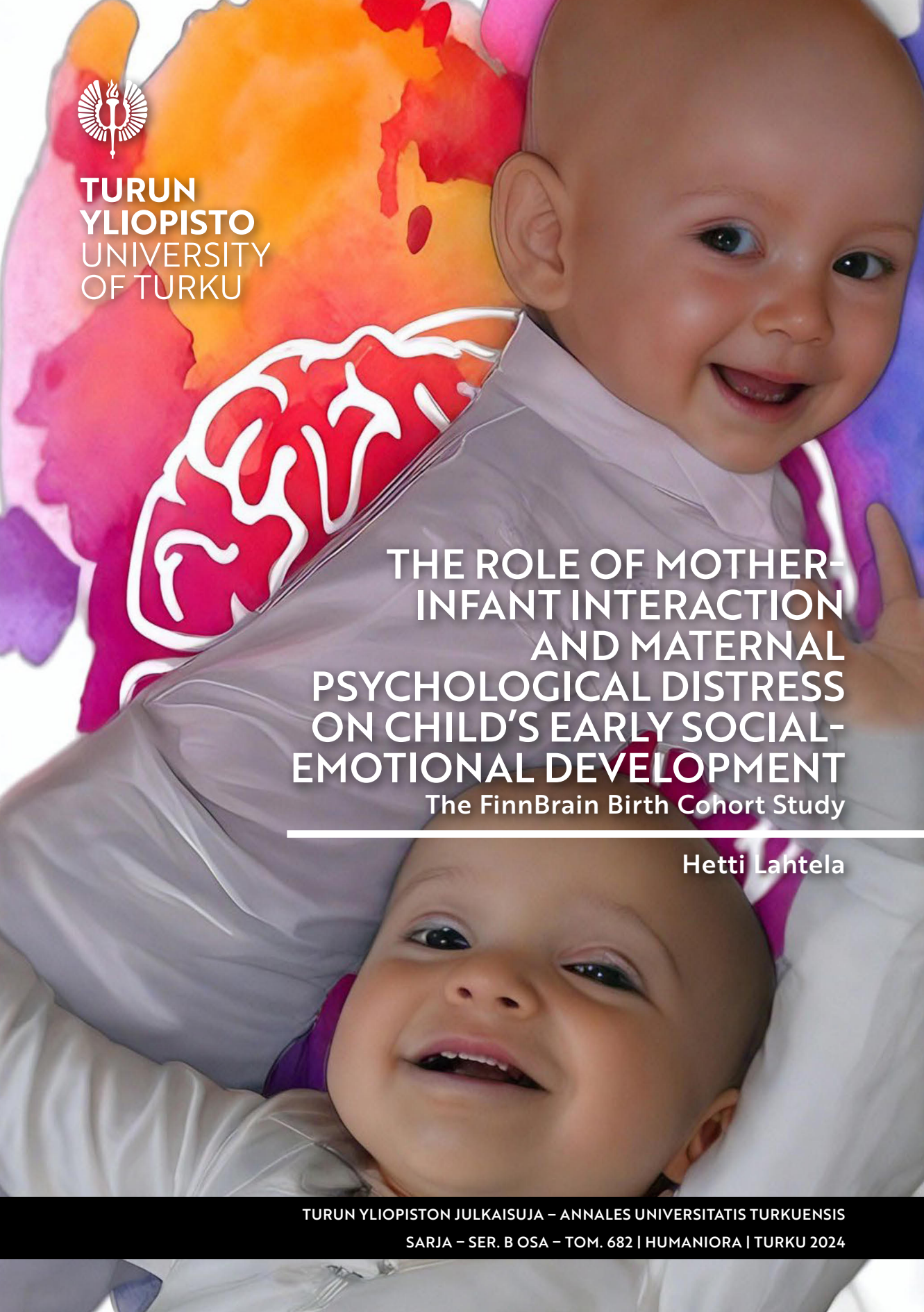

TURUN YLIOPISTO
UNIVERSITY OF TURKU

THE ROLE OF MOTHER-INFANT INTERACTION AND MATERNAL PSYCHOLOGICAL DISTRESS ON CHILD'S EARLY SOCIAL-EMOTIONAL DEVELOPMENT

The FinnBrain Birth Cohort Study

Hetti Lahtela

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To my children

UNIVERSITY OF TURKU
Faculty of Social Sciences
Department of Psychology and Speech-Language Pathology
Psychology
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ABSTRACT

Children's optimal social-emotional functioning is crucial for their adaptive behavior in different situations. Studies show that mother–infant interaction as well as maternal psychological distress pre- and postnatally associate with children's negative emotional reactivity and with their social-emotional problems and competencies. Little is known about how these factors are associated with the aforementioned child outcomes when assessed simultaneously. We also lack knowledge about the possible moderating role of mother–infant interaction on the associations between maternal psychological distress and children's negative emotional reactivity and social-emotional development.

The aim of this thesis was to investigate if 1) different types or timing of maternal pre- and postnatal psychological distress associate with different EA dimensions at 8 months of child's age, 2) mother–infant interaction at 8 months associates with children's negative emotional reactivity at 12, 24 and 30 months, and 3) mother–infant interaction at 8 months associates with children's social-emotional problems and social-emotional competencies at 24 and 48 months. In addition, the aim was to study the possible moderating effects of mother–infant interaction on the associations between maternal psychological distress and children's negative emotional reactivity and social-emotional development.

We found that maternal pre- and postnatal psychological distress was associated with mother–infant interaction. Furthermore, mother–infant interaction was associated with children's negative emotional reactivity at 24 months and social-emotional problems and social-emotional competencies at 24 months. Finally, maternal postnatal, but not prenatal, psychological distress was associated with children's negative emotional reactivity and social-emotional development.

Interventions to reduce problems in mother-infant interaction and maternal psychological distress are needed.

KEYWORDS: Mother–infant Interaction, Maternal Prenatal Psychological Distress, Maternal Postnatal Psychological Distress, Negative Emotional Reactivity, Social-emotional Problems, Social-Emotional Competence

TURUN YLIOPISTO
Yhteiskuntatieteellinen tiedekunta
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TIIVISTELMÄ

Lapsen optimaalinen sosioemotionaalinen kehitys on oleellista hänen toimintakykynsä kannalta. Äidin ja lapsen välisen vuorovaikutuksen sekä äidin raskaudenaikaisten ja synnytyksenjälkeisten mielialaoireiden tiedetään olevan yhteydessä lapsen kehitykseen. Vähemmän tiedetään siitä, miten ne ovat samanaikaisesti tarkasteltuina yhteydessä lapsen negatiiviseen tunnereagoivuuteen ja sosioemotionaaliseen kehitykseen. Lisää tietoa tarvitaan myön äidin ja lapsen välisen vuorovaikutuksen laadun muokkaavista vaikutuksista äidin mielialaoireiden ja lapsen kehityksen välisiin yhteyksiin.

Tutkimuksen tarkoitus oli tutkia yhteyksiä 1) äidin raskaudenaikaisen ja synnytyksen jälkeisen psyykkisen oireilun ja äidin ja lapsen välisen vuorovaikutuksen välillä lapsen ollessa 8 kk:n ikäinen 2) äidin ja lapsen välisen vuorovaikutuksen ja lapsen negatiivisen tunnereagoivuuden välillä lapsen ollessa 12, 24 ja 30 kk:n ikäinen ja 3) äidin ja lapsen välisen vuorovaikutuksen ja lapsen sosioemotionaalisten ongelmien ja sosiaalisen kompetenssin välillä lapsen ollessa 24 ja 48 kk:n ikäinen. Lisäksi tarkoitus oli tutkia äidin ja lapsen välisen vuorovaikutuksen mahdollisia muokkaavia vaikutuksia äidin psyykkisen oireilun ja lapsen kehityksen välisiin suhteisiin.

Tutkimuksessa havaittiin, että äidin raskaudenaikainen ja synnytyksenjälkeinen psyykkinen oireilu oli yhteydessä äidin ja lapsen väliseen vuorovaikutukseen. Lisäksi havaittiin, että äidin ja lapsen välinen vuorovaikutus oli yhteydessä lapsen negatiiviseen tunnereagoivuuteen ja lapsen sosioemotionaaliseen kehitykseen 24 kuukauden iässä. Havaitsimme myös, että äidin synnytyksenjälkeinen, mutta ei raskaudenaikainen mielialaoireilu oli yhteydessä lapsen negatiiviseen tunnereagoivuuteen ja sosioemotionaalisiin ongelmiin ja kompetenssiin 24 kk:n iässä.

Tarvitaan interventioita, jotka pyrkivät parantamaan äidin ja lapsen välistä vuorovaikutusta ja vähentämään äidin mielialaoireita.

ASIASANAT: Äidin ja lapsen välinen vuorovaikutus, äidin mielialaoireilu raskauden aikana ja synnytyksen jälkeen, lapsen negatiivinen tunnereagoivuus, lapsen sosioemotionaaliset ongelmat ja sosioemotionaalinen kompetenssi

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19.9.2024
Hetti Lahtela

Table of Contents

Tables

Figures

List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I Hakanen H., Flykt M., Sinervä E., Nolvi S., Kataja EL., Pelto J., Karlsson H., Karlsson L., Korja R. How maternal pre- and postnatal symptoms of depression and anxiety affect early mother-infant interaction? *Journal Affective Disorders*. 2019; 257; 83-90. http://doi.org/10.1016/j.jad.2019.06.048

II Lahtela H., Nolvi S., Flykt M., Kataja EL., Eskola E., Pelto J., Bridgett DJ., Karlsson H., Karlsson L., Korja R. Mother-infant interaction and maternal postnatal psychological distress are associated with negative emotional reactivity among infants and toddlers - A FinnBrain Birth Cohort study. *Infant Behavior and Development*. 2023; 72. https://doi.org/10.1016/j.infbeh.2023.101843

III Lahtela, H., Flykt, M., Nolvi, S., Kataja Eeva-Leena, Eskola Eeva, Tervahartiala Katja, Pelto Juho, Carter A.S., Karlsson H., Karlsson L., & Korja Riikka. Mother–Infant Interaction and Maternal Postnatal Psychological Distress Associate with Child's Social-Emotional Development During Early Childhood: A FinnBrain Birth Cohort Study. *Child Psychiatry and Human Development.* 2024. http://doi.org/10.1007/s10578-024-01694-2

1 Introduction

An infant is profoundly dependent on the environment that s/he is living in (Calkins & Hill, 2007), and the first developmental environment affecting the infant is the uterus. During pregnancy, the infant is affected through complex psychological and biological processes of the mother, as well as genetic factors influencing the transmission of parental psychological distress to the developing child (Stein et al., 2014). Maternal psychological distress is often conceptualized as anxiety and depressive symptoms (Grande et al., 2022; Howland et al., 2020) that an individual is exposed to during the prenatal and postnatal periods. The effects of maternal psychological distress during pregnancy on infants and children can persist even into adulthood (Glover & Capron, 2017; Pearson et al., 2013). Pregnancy and transition to parenthood are major events in a woman's life that include changes in the body, such as hormonal changes, changes in neurocognition, and changes in roles in her life (Pearson et al., 2012; Slomian et al., 2019). It seems that prenatal maternal psychological distress might also affect the neurocognitive changes in the mother that are meant to prepare her to respond sensitively to the infant's needs after birth, hence possibly altering mother–infant interaction through this process even after birth (Agrati & Lonstein, 2016; Pearson et al., 2012). Due to these big changes associated with the transition to parenthood, the perinatal period forms a risk for mental disorders, such as depression (Slomian et al., 2019) and anxiety (Field, 2017a, 2018). Maternal psychological distress pre- and postnatally is a known risk factor for compromised mother–infant interaction, such as lower bonding with the infant (Moehler et al., 2006) and less speech and smiling toward the infant (Righetti-Veltema et al., 2002).

In addition to pregnancy, the first two years of life are viewed as an important time of postnatal brain development in humans (Knickmeyer et al., 2008) where parenting, including mother–infant interaction (Grande et al., 2022), forms the fundamental psychological environment for the infant. Cultural and social contexts influence parenting. In addition, parental individual differences, such as a parent's own self-regulation ability, influence the mother–infant interaction (Sanders & Mazzucchelli, 2013). During infancy, being able to provide nurturance and good-quality parent–infant interaction for the baby are the most important roles of the

parents (Verhoeven et al., 2007). A parent's capacity to be sensitive (i.e., to read the child's signals, interpret them correctly, and respond to them promptly and accurately; Ainsworth, 1978; Biringen, 2014) is fundamental for healthy mother–infant interaction. One way to assess mother–child interaction and the quality of maternal caregiving is the emotional availability (EA) framework (Biringen, 2008), which views the mother–infant interaction as a dyadic process between the parent and the child.

Early postnatal environment, including mother–infant interaction and maternal psychological distress, is a crucial factor in shaping a child's development in several areas, including the child's temperamental outcomes, such as negative emotional reactivity and broader social-emotional development (Deans, 2020; Raby et al., 2015; Rogers et al., 2020). Temperament refers to biological-based individual differences in affectivity, activity, and self-regulation in infants and young children (Rothbart, 2011; Rothbart & Bates, 2006), which are shaped by maturation and environment. Negative emotional reactivity is the tendency to experience and express negative emotions (Rothbart, 1981), and elevated negative emotional reactivity is a risk factor for later psychopathology in children (De Pauw & Mervielde, 2010). Healthy social-emotional development is crucial for children's everyday functioning (Denham et al., 2009; Huber et al., 2019). Social-emotional problems are typically divided into behavioral (externalizing) symptoms, such as conduct problems, and emotional (internalizing) symptoms, such as anxiety symptoms and pronounced withdrawal (Briggs-Gowan et al., 2004; Huber et al., 2019). Social-emotional competence is an aspect of social-emotional development that highlights the social skills (Barnett et al., 2012).

Despite a vast body of work investigating and showing persisting associations between mother–infant interaction and child developmental outcomes and between maternal psychological distress and child developmental outcomes (Deans, 2020; Korhonen et al., 2012; Korja et al., 2017; O'Donnell et al., 2014; Raby et al., 2015), the relative contributions of mother–infant interaction and maternal psychological distress and the pre- vs. postnatal timing effects of maternal distress on different domains of child development such as negative emotional reactivity and social-emotional development has remained unclear (Galbally et al., 2017; Thomas et al., 2017). In addition, the results have been inconsistent with some studies indicating no effects of prenatal distress on child development (Thomas et al., 2017). Accordingly, there is growing evidence suggesting that the discrepancies in the results considering the associations between maternal psychological distress and child development might be the result of some moderating factors, such as the quality of mother–infant interaction (Thomas et al., 2017). Mother–infant interaction might buffer the harmful impact of maternal psychological distress on a child's social-emotional development and temperament, including negative emotional reactivity

(Belsky & Fearon, 2002; Grande et al., 2022; Mäntymaa et al., 2015; Wurster et al., 2020).

To summarize, the associations between mother–infant interaction and maternal psychological distress with children's negative emotional reactivity and social-emotional development have shown to exist. Yet, little is known about the unique roles of mother–infant interaction and maternal psychological distress during both the pre- and postnatal period, especially the possible moderating effects of mother–infant interaction on these associations. Hence, there is a need for a better understanding of the direct as well as the interaction effects of these factors on children's early social-emotional development in order to be able to better target the interventions to prevent problems in children's social-emotional development.

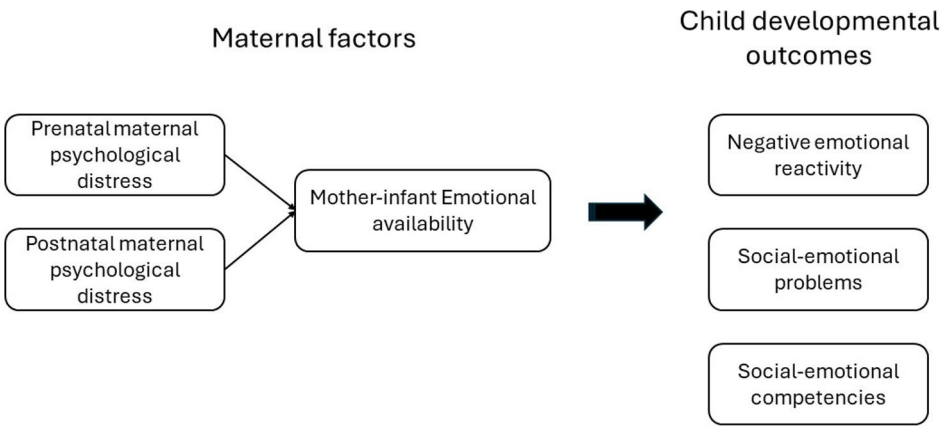

Figure 1. Theoretical model of the study.

2 Review of the Literature

2.1 Parenthood and mother–infant interaction

An infant is highly dependent on parenting, and high-quality parenting forms the foundation for an infant's neurocognitive and social-emotional development later in life (Calkins & Hill, 2007: Callaghan & Tottenham, 2016). The transition to parenthood starts with pregnancy and demands biological, psychological, and social changes that include re-organization of a woman's roles in her life and as a part of her family and mental representations of oneself and close relationships, including the baby (Broden 2006; Stern 1995). Neurocognitive and affective changes during pregnancy are meant to prepare the mother to be sensitive to the infant after birth. Representations about oneself as a parent and about her future child prepare future caregivers for parenthood and are an important part of the psychological process of pregnancy. Maternal psychological distress, cultural beliefs, and social support, including support from the partner, as well as the parenting that one has received as a baby herself, affect the pregnancy experience (Ahlqvist-Björkroth et al., 2016; Raphael-Leff 2010; Slade et al 2009; Stern 1995). The psychological processes of the mother aimed to enhance attachment and sensitivity in taking care of the baby continue to the postnatal period (Agrati & Lonstein, 2016). It has been shown that the quality of representations about the baby during the prenatal phase is associated with the quality of the parent–infant relationship (Benoit et al., 1997). It seems that prenatal maternal psychological distress might disrupt these neuroaffective changes and influence mother–infant interaction after birth through this process (Agrati & Lonstein, 2016; Pearson et al., 2012).

Bowlby (1969) started to advance knowledge on the fundamental effects of mother–infant interaction on child development decades ago with attachment theory. Attachment theory states that the child uses different attachment-related behaviors, such as smiling, crying, and clinging, to make the caregiver physically and emotionally available and uses the parent as a secure base in stressful situations. Based on the interactions between the primary caregiver and the child during the first year of life, the child forms an attachment relationship with the caregiver that can be either secure or insecure. If the mother is sensitive in the interactions with the infant, the infant is likely to form a secure attachment with the caretaker. These interactions

form a base on the internal working models/representations of oneself-with others (i.e., overall internal representations of relationship quality that guide the child's behavior in other relationships as well; Bowlby, 1969; Stern, 1995).

Children are highly dependend on the extrinsic regulation of negative emotions by their parents during their first years of life. Regulation of emotions is fostered in the context of early mother–child interaction (Behrendt et al., 2019). Securely attached (vs. insecurely attached) children tend to use their parents as a source of external emotion regulation when they are sad or distressed (Bowlby, 1969). When parents are sensitive (i.e., respond to their children's emotional cues in a warm and well-regulated style), infants' capacity to regulate their own emotions and behavior enhances (Bernier et al., 2010; Tronick & Gianino, 1986). Parent–infant interaction and sensitivity are associated with widespread areas of child development, including brain development (Davis et al., 2020; Kok et al., 2015) and cognitive development (Deans, 2020) as well as self-regulation in children (Bridgett et al., 2015). Children's emotion regulation capacity is firmly linked with social-emotional development (Behrendt et al., 2019; Eisenberg, Spinrad, et al., 2010). Other aspects of mother–infant interaction quality besides sensitivity have been shown to be associated with child development, but they have been studied less (Kim et al., 2014).

2.1.1 Emotional Availability (EA)

The EA framework expands attachment theory to asses mother–infant interaction in everyday life situations, not only in stress situations, where the attachment style is activated (Biringen et al., 2014). In addition to attachment theory, EA theory is based on the thoughts of Emde et al. (1985) that the parents' emotional, not mere physical, presence is crucial for the healthy dyadic quality of the parent–child relationship and the healthy development of a child (Biringen et al., 2014). EA is a widely used method to assess the quality of the parent–infant relationship, and the quality of EA has been shown to be associated with the child's attachment security (Kim et al., 2017). EA is also linked with a child's attachment style; a less sensitive, and passive/withdrawn, and emotionally less available style is associated with insecurity (Easterbrooks et al., 2012).

In the EA framework, sensitivity refers to the parent's ability to interact with the child in a warm, positive, and genuine manner and to read and respond to the child's emotional cues in a way that is well received by the child. Structuring refers to the parent's ability to scaffold and guide the child's activities and to set limits for the child when necessary in a way that is accepted by the child and is respectful and age appropriate (Biringen et al., 2014). Nonintrusiveness in the EA approach means that the adult can give the child an age-appropriate amount of space, respect the child's personality, and respond to the child's initiatives in the interaction (Biringen, 2008).

Nonhostility refers to an adult's ability to act nonaggressively toward the child. Hostility in such interactions can be covert or overt (Biringen, 2008) ranging from sarcasm to physical abuse. Child aspects in the EA framework include child responsiveness to the caregiver and child involvement of the caregiver. Responsiveness is viewed primarily as social and emotional responsiveness, and affectivity and responsiveness are key features of child responsiveness (Biringen et al., 2014). The child involvement of the adult assesses how the child is able to make initiatives to the adult for mutual play and activities in a way that is received by the adult (Biringen et al., 2014).

Parent's compromised EA is predictive of several child outcomes, such as lower school-readiness (Saunders et al., 2015), lower emotion-regulation (Little & Carter, 2005; Martins et al., 2012), and lower social competence (Howes, & Hong, 2008). These have been described in more detail in the EA theory framework.

2.1.2 Maternal psychological distress

Early life stress, such as parental psychological distress, compromised mother–infant interaction, abuse, or parental substance use disorder can explain 44.6 % of all the childhood onset mood, anxiety, behavioral disorders, and substance use problems during the life course (Green et al., 2010). Defining maternal psychological distress as combined anxiety and depressive symptoms is a common way to approach the phenomenom because of the comorbidity and similar effects of these symptoms during the pre- and postnatal periods on a developing child (Davis et al., 2011; Field, 2018; Howland et al., 2020; Pollack, 2005; Van den Bergh et al., 2020). According to a systematic review, perinatal depression affects about 11.9% of all mothers (Woody et al., 2017) with estimates ranging between 1.9% and 82.1% when using self-reports (Norhayati et al., 2015). Perinatal anxiety affects 8.1–29.2% of women worldwide, depending on the assessment method (Nielsen-Scott et al., 2022). Known risks for pre- and postnatal depression and anxiety include depression or anxiety previously in life (Howard et al., 2014), low social support, poor partner relationship quality (Norhayati et al., 2015), and low socioeconomic status (Dolbier et al., 2013). Maternal postnatal psychological distress has been shown to be associated with mother–infant interaction (Bernard et al., 2018; Campbell et al., 2007; Leerkes et al., 2015; Parfitt et al., 2013).

2.2 Child's social-emotional development

Healthy social-emotional development is critical for children's optimal long-term psychological functioning and well-being. Problems in social-emotional development place children at risk for different adverse outcomes, such as academic

difficulties and peer problems, in childhood and later in life (Coolahan et al., 2000; Denham et al., 2009; Huber et al., 2019). Social-emotional development is an umbrella concept that describes a variety of intra- and interpersonal skills (Malti & Noam, 2016). It comprises understanding, regulating, and expressing emotions in a way that is age appropriate (Malti, & Noam, 2016). In addition, socially and emotionally competent children are able to form and maintain positive relationships with peers by communicating their feelings and needs with others and regulating their feelings and behaviors in social settings (Campbell et al., 2016; Denham et al., 2009). As early social-emotional difficulties tend to continue over time (Briggs-Gowan et al., 2001), it is vital to increase knowledge about the risk factors for social-emotional problems in order to detect the problems early enough.

Children's intrinsic characteristics, such as effortful control (EC) and other self-regulatory capacities, are associated with their social-emotional problems and competence (Eisenberg et al., 2015; Spinrad et al., 2007). It has been shown that better EC is associated with better social competence in children (Eisenberg et al., 2014). In addition to the individual characteristics of the child, the early caregiving environment crucially affects the child's social-emotional development (Russell et al., 2016) through attachment quality and mother–infant interaction (Behrendt et al., 2019; Ranson & Urichuk, 2008). Maternal psychological distress during the prenatal period and early childhood is also associated with children's social-emotional development (Rogers et al., 2020).

2.2.1 Negative emotional reactivity in children

EC and emotional reactivity are usually conceptualized as constructs of infant temperament. In the psychobiological framework of temperament, temperament is referred to as "biologically based individual differences in emotional and behavioral reactivity and regulation" (Rothbart & Bates, 2006; Rothbart & Posner, 2011), which are shaped by heredity, experience and maturation (Rothbart, 1981). Self-regulation (EC) refers to modulation of these mainly automatic responses or reactivity (De Pauw & Mervielde, 2010) and includes "the efficiency of executive attention, including the ability to inhibit the dominant response, to plan, and to detect errors" (Rothbart & Bates, 2006). Negative emotional reactivity refers to elevated levels of expressing and experiencing negative emotions, comprising the intensity and threshold of these emotions (Rothbart et al., 2011). These include, for example, anger, fear, and sadness. In reactivity, the emotional and physical activity components are separated and emotional reactivity is divided into positive and negative emotional reactivity (De Pauw & Mervielde, 2010). Emotional reactivity is seen as a response to changes in both internal and external environments. Negative emotional reactivity also overlaps with infant crying (James-Roberts et al., 1995) and and a "difficult temperament" (Chess and Thomas, 1987). Negative emotional reactivity emerges early in life, around the age of 2–3 months (Rothbart, 2007).

Negative emotional reactivity is associated with later psychopathology such as attention deficit hyperactivity disorder (ADHD) as well as externalization and internalization in children (De Pauw & Mervielde, 2010; Wichstrøm et al., 2018) and is hence an important area of research in developmental psychology (De Pauw & Mervielde, 2010). Along with maturation and heredity, the manifestation of temperament can be influenced by external factors, such as mother–infant interaction and maternal psychological distress (Gartstein & Rothbart, 2003). Temperament is constantly changing as the child forms new experiences with the environment and learns new strategies to function in the social world through an enhanced capacity to self-regulate one's behavior and emotions. Temperamental features develop over time, especially during infancy and early childhood (Gartstein & Rothbart, 2003), as children's internal self-regulation capacity (i.e., EC) is amplified through parenting (Braungart-Rieker et al., 2010; Gartstein & Rothbart, 2003). This, in turn, can affect the manifestation of children's negative emotional reactivity as the child's self-regulation is amplified, which, in turn, reduces the mainly automatic expression of negative emotional reactivity (Braungart-Rieker et al., 2010; Calkins, & Hill, 2007; Gartstein & Rothbart, 2003).

2.2.2 Social emotional problems and – competencies

Problems in social-emotional development are typically characterized as behavioral (externalizing) and emotional (internalizing) symptoms (Briggs-Gowan et al., 2004). Behavioral symptoms include emotional and behavioral lability and may include conduct problems, aggressive behavior, impulsiveness, and hyperactive behavior (Achenbach & Edelbrock, 1978; Briggs-Gowan et al., 2004). Internalizing symptoms refer to anxiety, depression, and pronounced withdrawal from social situations (Huber et al., 2019). Social-emotional competence is an aspect of social-emotional development, highlighting the social component of broader social-emotional development, which also includes cognitive, emotional, and regulative aspects (Campbell et al., 2016).

2.3 The mechanisms: Psychological and biological pathways affecting children's social-emotional development

When humans are exposed to stress early in life, including maternal psychological distress starting in pregnancy, different biological systems in the fetus activate in order to adapt as a response to the stressor to be more able to function in that particular changed environment (Herzberg & Gunnar, 2020). The prenatal programming model (i.e. the "Barker hypothesis"; Barker, 1998; Barker, 2004) states that these programming effects might lead to persisting changes in the fetus's biology and behavior later in life and is followed by detrimental outcomes in the child's development in different areas (O'Donnell et al., 2014). The prenatal programming model is one of the prevalent theories used to explain the mechanisms underlying the associations between maternal psychological distress during gestation and a child's temperamental outcomes and self-regulatory problems. Maternal prenatal psychological distress can alter fetal brain functioning in the prefrontal–hypothalamic–amygdala and dopaminergic circuits. According to the prenatal programming model, the fetus is affected by elevated levels of maternal stress hormones via intrauterine exposure (Davis, & Sandman, 2006). The effects of prenatal maternal psychological distress on a fetus's central nervous system functioning seem to be at least partially mediated by alterations in hypothalamic–pituitary–adrenal (HPA) axis functioning (Smith & Pollak, 2020). Maternal stress hormones affect the activation of the HPA axis, which is one of the major stress systems in the human body and is crucial for the management of stress (Davis & Sandman, 2006; Dunlavey, 2018). The end product of the HPA system is glucocorticoids, cortisol hormone which has effects on many organs in the body and passes through the placenta (Sandman & Davis, 2012). Increased activation of the HPA system has been shown to relate to shortened gestation and impaired fetal

growth (Bolten et al., 2011), and repeatedly heightened levels of cortisol might lead to negative effects in the brain (Herzberg & Gunnar, 2020; Rogers et al., 2020).

Prenatal depression and anxiety have also been shown to be associated with compromised blood flow, nutrients, and oxygen to the developing fetus, which might lead to harmful changes in the development of the child's nervous system (Sandman et al., 2011; Talge et al., 2007; Teixeira et al., 1999). In addition, it has been shown that maternal distress might reduce the function of the placental enzyme 11B-HSD2, which works to transform the cortisol hormone into inactive cortisone and hence might enhance the fetus's exposure to maternal stresshormones (Madigan et al., 2018). The human brain is susceptible to programming effects during the prenatal and early postnatal periods because it undergoes dramatic growth and changes during that time (Sandman & Davis, 2012).

Postnatal maternal psychological distress is thought to affect child development through a different route than prenatal psychological distress, namely through impaired mother–infant interaction (Bernard et al., 2018). Postnatal depressive symptoms have been shown to be associated with lower levels of maternal sensitivity at least during the first year of children's life (Behrendt et al., 2016; Bernard et al., 2018; S. Campbell et al., 2007; Leerkes et al., 2015). These associations are also seen concerning the subclinical levels of depressive symptoms, not only clinically defined depression in mothers after birth (Moehler et al., 2006). In addition, maternal postnatal anxiety has been shown to be associated with lower sensitivity of a mother toward her children (Ierardi et al., 2019), lower responsiveness of a mother to infant emotional cues (Warnock et al., 2016), less bonding with the infant (Tietz et al., 2014), and insecure attachment quality between a mother and her infant (Ohoka et al., 2014). Studies have shown that maternal sensitivity and responsiveness are directly associated with infant, toddler, and school-aged children's social-emotional development, including social competence (Behrendt et al., 2019; Brophy-Herb et al., 2011; Ranson & Urichuk, 2008; Russell et al., 2016). Specifically, it has been shown that better mother–child interaction enhances children's executive functioning and emotion-regulation capacity, which, in turn, predicts less social-emotional problems and higher social competence in children (Behrendt et al., 2019; Spinrad et al., 2007). When children are better able to regulate their emotions and behaviors it is easier for them to interact with their social partners in an effective way (Behrendt et al., 2019; Page et al., 2010).

2.3.1 The effects of maternal psychological distress and mother–infant interaction on a child's negative emotional reactivity and social-emotional development

Accordingly, studies have shown associations between prenatal distress and different temperamental features in infants, such as higher infant fearfulness (Nolvi et al., 2019; Sandman et al., 2011), hyperactivity (Gerardin, 2011), and difficult temperament (Edhborg et al., 2000). Elevated maternal psychological distress prenatally, concerning both depressive and anxiety symptoms, has also been shown to be associated with children's overall higher negative emotional reactivity (Bolten et al., 2012; Grande et al., 2022). In systematic reviews, the associations between prenatal maternal psychological distress and a child's negative emotional reactivity from infancy to toddlerhood have been shown to be small to moderate and unrelated to a specific time point in pregnancy (Korja et al., 2017; Rogers et al., 2020). In addition, associations between prenatal psychological distress and children's social-emotional outcomes have been reported (Rees et al., 2019; Rogers et al., 2020). Prenatal maternal psychological distress has been shown to be associated with children's social-emotional development, such as internalizing and externalizing symptoms, even until adolescence, with effect sizes being small to moderate (Frigerio & Nazzari, 2021; Madigan et al., 2018). Prenatal maternal psychological distress has also been shown to be associated with a child's social competence in adolescence (Korhonen et al., 2012). Associations regarding prenatal maternal psychological distress and social-emotional development were evident from early childhood to adolescence, with the exception of internalizing symptoms, which were evident only in early childhood in comparison to externalizing symptoms (Rogers et al., 2020).

Concerning the effects of postnatal maternal psychological distress, it has been shown that postnatal depressive symptoms are also associated with negative emotional reactivity in children, such as infant distress (Tikotzky et al., 2010), overall negative emotionality (Werner et al., 2013), and the intensity of reactions in toddlerhood (Lin et al., 2017). These effects can extend to the preschool period (Swales et al., 2018) and even to adolescence (Glynn et al., 2018). It has been shown that maternal postnatal psychological distress, including both depressive and anxiety symptoms, is associated with children's increased social-emotional problems and lower social competence (Dix & Yan, 2014; Glasheen et al., 2010; Palmer et al., 2018). The findings included associations with a child's overall social-emotional problems, as well as both externalizing and internalizing symptoms (Rogers et al., 2020). In addition, maternal depressive symptoms have been shown to be associated with children's compromised social competence such as prosocial behavior, including helping others and beeing popular and accepted by peers in early childhood

(NICHD Early Child Care Research Network, 1999), early school age (Kersten-Alvarez et al., 2012), and middle childhood (Luoma et al., 2001).

Regarding the effects of the maternal caregiving environment, the quality of mother–infant interaction has been shown to be associated with a child's negative emotional reactivity (Bernier et al., 2010; Bridgett et al., 2015) as well as social-emotional development. Higher EA in the mother–infant dyad has been shown to be associated with children's better emotion regulation in infancy (Eisenberg et al., 2015; Kogan & Carter, 1996; Little & Carter, 2005). Higher verbal structuring has shown to associate with increased prosocial behavior in toddlers (Dahl et al., 2017). Maternal negativity/hostility has been shown to be associated with increased frustration and more behavior problems in children (Elam et al., 2014; Klein et al., 2018). Maternal scaffolding (i.e., structuring) has been shown to be associated with better self-regulation in some children of preschool age (Augustine & Stifter, 2019) and with children's social-emotional development, such as increased prosocial behavior (Dahl et al., 2017; Page et al., 2010). More restrictive control (i.e., over-intrusive parenting) has been shown to be associated with decreased self-regulation EC and higher negative emotional reactivity in children (Eisenberg et al., 2015; Paulussen-Hoogeboom et al., 2007). It has been shown that the effects of a lower quality of mother–infant interaction on children's higher negative emotionality are accentuated in the context of other risk factors such as lower socioeconomic status (Paulussen-Hoogeboom et al., 2007). Children's intrinsic characteristics, such as higher EC, also contribute to social-emotional development, but some studies show that early caregiving quality exceeds the impact of a child's internal characteristics on child development (Russell et al., 2016). Still, the associations are also multidirectional. For example, lower EC has been shown to be associated with more externalizing symptoms, which increase intrusiveness in parenting and intrusive parenting predicts lower EC (Eisenberg et al., 2015).

2.4 The moderating role of mother–infant interaction on the associations between maternal psychological distress and child development

The direct associations between maternal psychological pre- and postnatal distress and children's compromised development, including higher negative emotionality and heightened social-emotional problems, seem to exist, but the associations have been inconsistent, as some studies did not find any moderating effects, and the effect sizes have varied from small to moderate from study to study (Rogers et al., 2020; Stein et al., 2014; Thomas et al., 2017). The results have been more robust when the levels of maternal psychological distress has been measured at the clinical level vs.

subclinical/symptoms level only, but the associations have not been found in all the studies (Korja et al., 2017; Madigan et al., 2018). Hence, it seems that some factors, such as mother–infant interaction, can ameliorate these effects. Until recent years, this area has not been a focus of interest, but some studies have found evidence for the hypothesis that higher quality of mother–infant interaction, including higher EA, moderates the associations between maternal psychological distress pre- and postnatally and child negative emotional reactivity, as well as social-emotional development (Grande et al., 2022; Mäntymaa et al., 2015; Wurster et al., 2020). It has been shown that maternal sensitivity moderates the effects of maternal prenatal psychological distress by decreasing children's negative emotional reactivity in infancy and toddlerhood in the case of higher sensitivity (Grande et al., 2022; Grant et al., 2010; Kaplan et al., 2008a). Bolten et al. (2012) found that maternal self-efficacy, which also reflects higher sensitivity, affected the associations between maternal prenatal psychological distress and negative emotional reactivity in early infancy. Considering children's social-emotional development, it has been shown that higher EA and shared pleasure in mother–infant interaction moderate the associations between parent's postnatal psychological distress and children's social-emotional problems during toddlerhood (internalizing and externalizing) (Mäntymaa et al., 2015; Wurster et al., 2020). The higher the EA, the less heightened postnatal distress increases children's social-emotional problems. The moderating effects of high-quality mother–infant interaction on children's later psychopathology exceeds the pre- and early postnatal periods. It has been shown that secure maternal attachment for preschool-aged children moderates the association between mother's depressive symptoms and children's subsequent depressive symptoms (Milan et al., 2009). In addition, a fairly recent study showed that in humans, higher EA can alter the cortisol reactivity of prenatally maternal stress-exposed children, providing some preliminary evidence of the biological systems behind the possible moderating effects (Nazzari et al., 2022). Some of the studies have measured moderations with outcomes such as cortisol reactivity, but as there are a fairly limited number of studies about the moderative effects of mother–infant interaction on the associations between maternal prenatal distress and children's social-emotional outcomes, the results in close concepts might indicate that there are, in fact, some moderative effects.

3 Aims

The aims of this study were, first, to study the associations between maternal pre- and postnatal psychological distress and mother–infant interaction, second, to study the associations between mother–infant interaction and maternal psychological distress and child negative emotional reactivity at different time points in early childhood and, third, to study the associations between mother–infant interaction and maternal psychological distress and child's social-emotional development during early childhood at different time points. In addition, we studied the possible moderating effects of mother–infant interaction on the associations between maternal psychological distress and children's negative emotional reactivity and children's social-emotional outcomes.

Specifically, our research questions are as follows:

1) Do different types- (depressive and anxiety symptoms) and timing (gestational weeks 14, 24, and 34 and postnatal) of maternal psychological distress associate with different EA dimensions in mother–infant interaction in infancy? (Study I)
2) Does maternal EA in infancy and maternal psychological distress pre- and postnatally associate with infant and toddler negative emotional reactivity measured with a) laboratory observations and b) mother reports of child temperament? (Study II)
3) How do maternal EA and maternal psychological distress pre- and postnatally associate with children's social-emotional development during early childhood, measured with mother reports of child development? (Study III)
4) Does EA moderate the possible associations between maternal psychological distress and children's negative emotional reactivity or children's social-emotional development (Studies II and III).

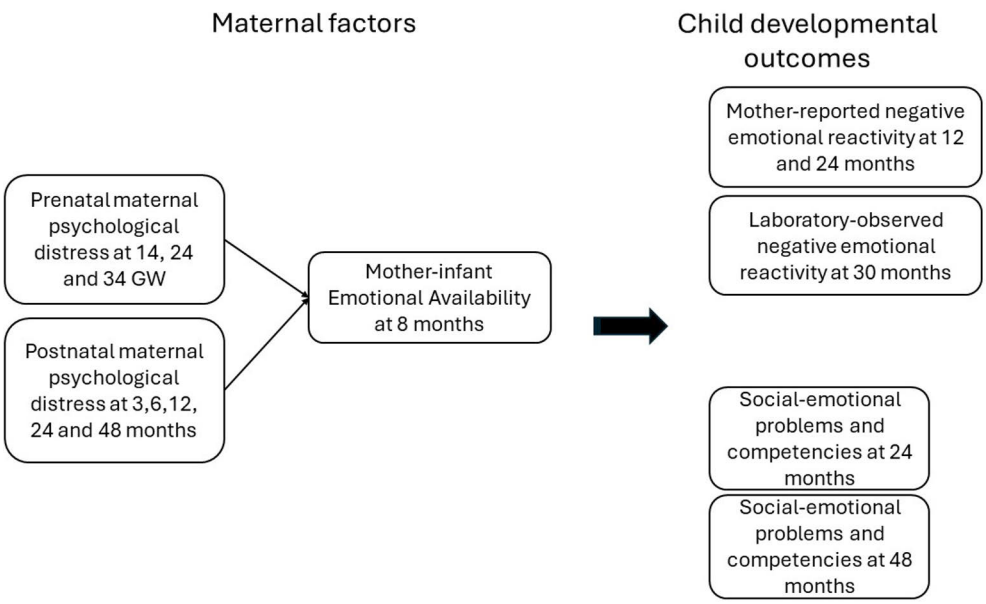

Figure 2. Design of the study.

4 Materials and methods

4.1 Study design and participants

This research was a sub study conducted in a larger FinnBrain birth cohort study in Finland that aims to examine the effects of early-life stress on child neurodevelopment and later psychiatric and somatic health and illnesses (Karlsson et al., 2018). The cohort population was recruited from general ultrasound visits by pregnant women during gestational week 12, and both parents had the opportunity to participate. All participants were ethnically Caucasian. The participating families were recruited from December 2011 to April 2015 from the South-Western Hospital District and the Åland Islands in Finland. Altogether, 3,808 families decided to participate in the FinnBrain birth cohort study. From the larger cohort, a smaller so-called focus cohort (N = 1,227) was formed based on the highest and lowest quartiles of self-reported parental prenatal psychological distress in the cohort. The criteria for forming the focus cohort, a nested case-control study, were determined by using the first 500 participant mothers' questionnaire data in exploratory analyses and establishing cut-points for the approximately highest and lowest 25th percentiles of maternal psychological distress during pregnancy. For the selection of the focus cohort, prenatal psychological distress was defined as maternal levels of depression, general anxiety, and pregnancy-related anxiety during the three prenatal data collection points (at 14, 24, and 34 gestational weeks). Two positive screens over the selected cut-points (i.e., twice using the same instrument and once using two different instruments) were conducted to identify cases of high prenatal distress. The selected cut-off points according to the quartiles were as follows: for depression, the Edinburgh Postnatal Depression Scale (EPDS) > 11 points/maximum score of 30; for anxiety, Symptom Checklist–90 Revised (SCL-90 General Anxiety Scale) > 9 points/maximum score of 40; and for pregnancy anxiety, Pregnancy-Related Anxiety Questionnaire Revised > 33 points/maximum score of 50. The controls scored within the lowest quartile on the questionnaires at every measurement point during pregnancy: EPDS < 7 points, SCL-90 < 5 points, and the Pregnancy-Related Anxiety Questionnaire Revised < 26 points. Later, the sample was enriched with mothers who received scores over the selected cut-points in one of the questionnaires during

pregnancy and their children. These families were studied more intensively, since the objective was to asses the same families as intensively as possible. These families were invited to participate in the Child Development and Parental Functioning Lab study visits and asked to fill out various questionnaires at different time points. The focus cohort was originally formed to ensure the largest possible variation in the symptoms of prenatal depression and anxiety.

4.1.1 Participants in studies I-III

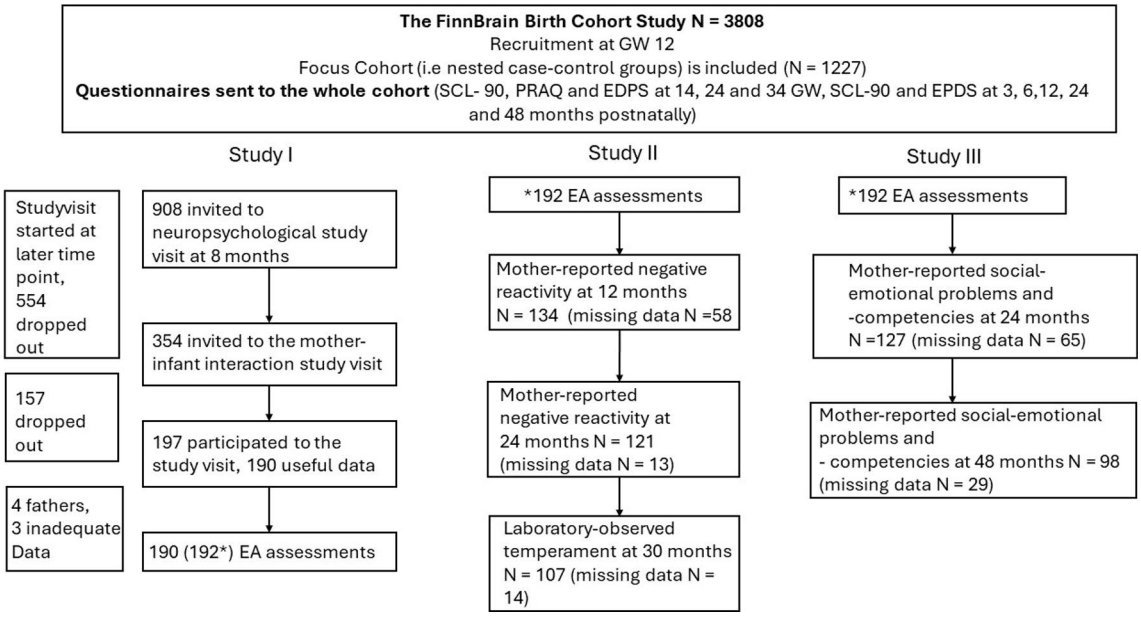

Figure 3. Flowchart of the enrollment of study participants.

Regarding Study I, the assessments started at a time point, where a part of the babies had already passed the age of 8 months. Hence, 908 families from the focus cohort participants were contacted, and 694 were reached out to and invited to join a more intensive developmental psychology study visit at 8 months of their children's age. The collection of data on mother–infant interactions were added later in the protocol of the FinnBrain Child Development and Parental Functioning Lab study visit at 8 months, which led to a smaller subsample than in the whole study visit. For the mother–infant interaction assessments, 354 families were contacted and invited to participate in the study visit when the child was 8 months of age. Of the families invited, 197 (55,7%) participated in the mother-child interaction evaluation. Seven participants were excluded either due to inadequate data (n = 3), or because they

were fathers instead of mothers (n = 4). The final sample size for this interaction substudy was 190. The initial group design (high vs. low distress group) was not utilized in this study, but 73 families were part of the initial high distress group (criteria above), and 117 were control families. Of the 190 participating infants, 50% were boys. The participants who took part in the mother–child interaction assessments were more often highly educated (t = 2.82, $p = 0.005$) and primiparous (t = −0.2.17, $p = 0.031$) than the invited non-participants. The focus cohort, which was the population of recruitment, resembled the source population except for the lower prevalence of younger, multiparous, and smoking women in the cohort. In addition, the prevalence of preterm births was lower in the cohort than in all deliveries at Turku University Hospital (Karlsson et al., 2018).

Concerning Study II, the same mothers who agreed to participate in the Study I mother–infant interaction assessments were the participants of the study. Of those families, 197 participated in the assessment, from which 192 (54,2 %) were included in the study (4 were fathers instead of mothers 1 for inadequate data) which formed the basis of the sample used in the present study. Those who agreed to participate were slightly older ($t = 2.38$, $p = 0.02$) and more highly educated than the invited non-participants (χ^2 (2) = 14.07, $p = 0.001$). The same families were invited to participate in a follow-up visit at 30 months, during which the laboratory assessments regarding the child's negative emotional reactivity were performed. Altogether, 107 (55,7 %) mother–infant pairs who had been assessed at eight months participated in the assessment of the child's negative reactivity. From these 134 (69,8 %) mothers filled in the questionnaires when the children were 12 months old and again 121 (63 %) when the children were 24 months old. The participants attending the study visits at both 8 and 30 months differed from those who participated only in the eight-month study visit in terms of parity; more participants were primiparous: $\chi^2 = 5.19$ (1), $p = 0.02$. However, the participants did not differ in terms of mother's age, level of education, monthly income, or child's sex.

Regarding Study III, again, families from the focus cohort enriched by other actively participating families were invited to participate (N = 354) in the Child Development and Parental Functioning Lab study visits when the child was eight months old. Of these, 192 participated and were analyzed (54.2 %). The same mothers were asked to complete questionnaires concerning their children's social-emotional development at 2 and 4 years of their children's age, where 127 and 98 mothers agreed to participate at two years (35.9 %) and 4 years (27.7 %), respectively. Accordingly, the final samples used in the analyses were 127 mothers and their 2-year-old children and 98 mothers and their 4-year-old children. The mothers who participated in the eight-month study visit and who completed the children's social-emotional development questionnaire at two years had a higher income ($\chi^2 = 10.4$ $p = .015$) and higher education level ($\chi^2 = 12.7$, $p = .002$) than

those who dropped out after the eight-months study visit. Further, the mothers who had participated in the eight-months study visit and completed the social-emotional development questionnaire at four years demonstrated a greater likelihood of being primiparous ($\chi^2 = 4.7$, $p = .03$), having a higher education level ($\chi^2 = 10.0$, $p = .01$) and having a higher income ($\chi^2 = 9.4$, $p = .03$) than the mothers who dropped out after the eight-months study visit. Depressive and anxiety symptom questionnaires were also completed at 14, 24, and 34 gestational weeks and at 3, 6, 12, 24, and 48 months postpartum (excluding the anxiety questionnaire at 12 months).

Table 1. Demographic characteristics of the samples in the studies I–III.

	Study I (N= 192)	**Study II (N = 107)**	**Study III (N = 127 at 2 years / N = 94 at 4 years)**
Education (%)			
Low	23.9	19.8	17.1/ 15.6
Middle	38.3	40.6	37.4/ 37.5
High	37.8	39.6	45.5/ 46.9
Monthly income (%)			
Very low	15.2	15.1	26.8/ 25
Low	56.7	54.7	61.8/ 63.5
Middle	18.5	27.4	10.6/ 9.4
High	9.5	2.8	0.8/ 2.1
Primiparous (%)	56.9	64.2	61.8/48.9
Infant sex (male)	50	51.4	48.8/ 50
Maternal age (mean, SD)	31.2(4.1)	31.3 (4.1)	31.5(4.0)/ 31.7(4.1)

[a] Part of secondary or secondary school, [b] High school or vocational school. [c] University/polytechnic or higher, [d] Very low ≤ 1000 €; low = 1001-2000 €; middle = 2001-3000 €; high >3001 €

4.2 Procedure

The participants filled out the questionnaires regarding background information at gestational week 14. The questions included information about the level of education, monthly income, economic satisfaction, and parity. In addition, information concerning the mother's age and perinatal status (gestational weeks at birth, Apgar scores, birth weight, and infant biological sex at birth) was received from national birth registries (data from national birth registries, National Institute for Health and Welfare). Mothers filled out questionnaires concerning psychological distress (anxiety and depressive symptoms) at gestational weeks 14, 24, and 34 and at 3, 6, 12, 24 and 48 months after birth (excluding the anxiety symptoms questionnaire at 12 months after birth).

At 8 and 30 months, we invited the families to visit the FinnBrain study's Child Development and Parental Functioning Lab to assess their children's cognitive and psychological development. As a part of the study visits mother–infant interactions were observed at 8 months, and structured assessments of children's temperament were completed at 30 months. A psychologist or an advanced psychology student conducted the study visits. Mother–child interaction was assessed in a video-recorded free-play situation when the child was eight months of age. The mother was offered a standard set of toys and asked to play for 20 minutes together with her child, as they usually would at home. The video-recorded free-play situations were analyzed with the EA scales (Biringen, 2008; 4th edition, see the measures below). The data on laboratory observations of child negative reactivity were collected during the 30-month study visit using a standardized observation method, the Preschool Laboratory Temperament Assessment Battery (Goldsmith et al., 1999).

Questionnaires concerning child development were collected at different time points. The mothers completed the temperament questionnaires when the children were 12 and 24 months old (IBQ-R and ECBQ). In addition, mothers filled out questionnaires concerning their child's social-emotional development at 24 months using the Brief Infant-Toddler Social and Emotional Assessment (BITSEA) and at 48 months using the Strengths and Difficulties Questionnaire (SDQ).

Figure 4. Mother-infant interaction assessment at eight months of child's age.

4.3 Measures

4.3.1 Emotional Availability

Mother–infant interactions were coded using the EA Scales (EAS, Biringen, 2008: 4th edition), which comprise four adult and two child dimensions to describe the interactions between the adult and child. Twenty-minute free-play sessions were video-recorded, and the mothers were instructed to play with their infants, as they usually would at home, with or without age-appropriate toys offered by the lab. The adult scales included adult sensitivity, structuring, nonintrusiveness, and nonhostility, and the child scales included responsiveness and the child's involvement of the adult (Biringen, 2008). Each scale reflects a distinct quality of caregiving. In the EA framework, a parent's ability to interact with a child is viewed dyadically; that is, the quality of the interaction is evaluated based on the reactions of the child (Biringen, 1998). This means that the mother can not "look good" without the child being emotionally responsive. EA is based on attachment theory and has been shown to be correlated with attachment security (McConnell et al., 2020) but expands the importance of the dyadic and emotional aspects in the interaction (Biringen et al., 2014).

In the EA framework, sensitivity is viewed as a parent's ability to interact with their child in a warm, positive, and genuine way and to respond to their emotional cues in a way that the child receives mutually emotionally available. Structuring refers to a parent's ability to scaffold and guide their child's activities and to set limits for the child when necessary in ways that the child accepts and that are age-appropriate (Biringen et al., 2014). Nonintrusiveness refers to a parent's ability to give their child an age-appropriate amount of space, respect their independence, and respond to their initiatives during interactions (Biringen, 2008). Finally, nonhostility means that the adult acts in a nonaggressive manner toward their child (Biringen, 2008). Hostility in such interactions can be covert or overt (Biringen, 2008) and can range from sarcasm to physical abuse. Child responsiveness is characterized by the child's ability to be in an emotionally healthy-enough interaction with the adult and be able to regulate one's affect and behavior with the help of the adult, whereas child involvement is defined as being able to make initiatives toward the adult into play and other interactions that the adult is responding to. In the fourth edition of the EA scale, each dimension is scored on a 7-point scale to achieve a direct score that describes the overall quality of the interaction. Scores from 1–2 on all six scales are considered highly problematic, scores from 2.5–3.5 indicate detachment in the relationship, and scores from 4–5 indicate complicated EA. Scores from 5.5–7 indicate an emotionally available and healthy EA mother–infant relationship (Biringen, 2008). Coders for EA went through authorized online training and were

certified for the method (www.emotionalavailability.com). Two blinded trained coders who had shown reliability, as recommended in the EA guidelines, performed the interaction data coding. The intraclass correlations were 0.80 for sensitivity, 0.72 for structuring, 0.85 for nonintrusiveness, 0.70 for nonhostility, 0.78 for child responsiveness, and 0.90 for child involvement. The scale scores were used as continuous variables.

4.3.2 Maternal anxiety and depressive symptoms

We used the EPDS to measure depressive symptoms. It is a widely used self-report evaluating depressive symptoms and is based on a 10-item scale, all of which have four possible responses ranging from 0–3. The minimum total score is 0, and the maximum score is 30 (Cox et al., 1987). The EPDS has been shown to be a valid measure for use during pregnancy as well as postnatally (Bergink et al., 2011). In this study, the sum of the item scores was used as a continuous variable, and the relevant questions were reversed-scored before calculating the total score. Internal consistency was adequate: Cronbach's $\alpha = 0.85–0.91$.

Regarding general anxiety the symptoms were measured using the anxiety subscale from the SCL-90, which is a valid questionnaire for measuring different psychological symptoms, such as anxiety, depression, and obsessive–compulsive disorder (Derogatis et al., 1973; Holi et al., 1998). The sum of the item scores was used as a continuous variable. The internal consistency of the SCL-90 was adequate: Cronbach's $\alpha = 0.83–0.91$.

In Study I, also pregnancy-related anxiety was measured. This was done using the Pregnancy-Related Anxiety Questionnaire, Revised 2 (PRAQ-R2; Huizink et al., 2016) at gwk 24 and 34 which is a modified version of the original PRAQ-R used to examine pregnancy-related anxiety (Huizink et al., 2016). PRAQ-R2 contains three scales: Fear of giving birth, Fear of bearing a physically or mentally handicapped child and Concern about one's appearance. Each scale has 10 items and the mothers answer on a scale from 1 to 5 with the total maximum of 50. The sum of the item scores was used as a continuous variable. The questionnaire showed good internal consistency ($\alpha = 0.85–.86$). Regarding Study I depressive symptoms and anxiety symptoms were assessed separately because we were interested in the specific effects of distress symptoms on mother–infant interaction. In Studies II and III, our main objectives were to investigate differences between pre- vs. postnatal maternal psychological distress and mother–infant interaction in relations to children's negative emotional reactivity and social-emotional development. Hence, combined total scores of prenatal anxiety and depressive symptoms and combined total scores of postnatal anxiety and depressive symptoms were used in the analyses. The combined scores for prenatal distress were formed by first calculating the means of

EPDS and SCL-90 over gestational weeks 14, 24, and 34 and then standardizing and summing them. We calculated the postnatal scores in a similar manner, combining the standardized sums of the postnatal scores measured at 3, 6, 12, 24, and 48 months.

4.3.3 Child's negative emotional reactivity

4.3.3.1 Parental reports of a child's negative emotional reactivity

At 12 months of child age, the Infant Behavior Questionnaire—Revised Short Form (IBQ-R) was used to evaluate children's negative emotional reactivity (Gartstein & Rothbart, 2003). At 24 months of age, the Early Childhood Behavior Questionnaire (ECBQ) (Putnam et al., 2006) was used to evaluate negative reactivity. Both questionnaires included several subscales that load on three factors: 1) negative affectivity (hereafter referred to as "negative emotional reactivity"), 2) surgency or extraversion, and 3) orienting or effortful control. Both are widely used, reliable, and valid questionnaires for assessing negative reactivity in early childhood (Gartstein & Rothbart, 2003; Parade & Leerkes, 2008; Putnam et al., 2006, 2014). In this study (Study II), we used data on negative reactivity collected at both time points. In both tools, the parents were asked to assess their children's behaviors in different daily life situations during the previous week or two, such as "When placed on his/her back, how often did the baby fuss or protest?" or "How often during the last week did the baby startle to a sudden or loud noise?". The IBQ-R includes 91 items, and responses are scored from 1–7; higher scores reflect higher levels of the child's negative emotional reactivity. The Negative Reactivity Scale in the IBQ-R includes 25 items and comprises four subscales: distress in reaction to limitations, fearfulness, sadness, and falling reactivity. In the present study (Study II), the negative reactivity scale in infancy showed good internal consistency ($\alpha = 0.84$).

The ECBQ's short form includes 107 items which are scored on a scale from 1–7. The Negative Reactivity Scale includes 48 items and the following subscales: discomfort, fear, sadness, frustration, soothability, motor activation, perceptual sensitivity, and shyness. The questionnaire includes questions to describe frequently occurring contexts, such as "when told no, how often did your child,": "sit quietly and watch," "become sadly tearful," etc. (Putnam et al., 2006). This scale showed good internal consistency in the present study ($\alpha = 0.88$). In this study, the mother's evaluations of the children's negative reactivity were used.

4.3.3.2 Laboratory-observed negative emotional reactivity

The data concerning the laboratory observations of children's negative emotional reactivity were collected at the 30-month study visit using a structured and

standardized observation method, the Preschool Laboratory Temperament Assessment Battery (The Lab-Tab) (Goldsmith et al., 1999). The instrument includes several emotion-eliciting tasks/episodes for assessing behavior related to various temperament attributes, including negative reactivity. In this study (Study II), we studied negative reactivity using the "The Attractive Toy in a Transparent Box" episode, which was designed to elicit frustration or anger and sadness. In this task, the experimenter presented attractive toys to the child, and the child was asked to pick up the set of toys with which they wanted to play. The experimenter placed the toys in a locked transparent plastic box and removed the right key, giving the child a set of wrong keys. The child was then asked to open the box to play with the toys after opening the box. The parents stayed with the children in the room for four minutes, and the experimenter left the room as instructed in the manual. The parents were given instructions not to participate in the task by helping the children but to encourage them to keep trying if they stopped attempting to open the box.

A trained psychologist or psychology student video-recorded and coded the episode in accordance with the Lab-Tab manual. The task was divided into four one-minute intervals, each of which included six epochs of 10 seconds. For each scale, the peak intensity of a coded behavior per epoch was used to score the intensity of the behavior, which reflected the child's negative reactivity. We coded and used the following indicators in this study: anger expression (on a scale from 0–3), presence of bodily anger (on a scale from 0–3), intensity of frustration (on a scale from 0–3), presence of protest vocalizations (on a scale from 0–3), reflecting anger and frustration, intensity of sadness expression (on a scale from 0–3), and presence of bodily sadness (on a scale from 0–1), which reflected overall sadness. Anger expression was based on the amount of anger expressed on the child's face, whereas the presence of bodily anger reflected the amount of bodily anger, such as bodily tension or temper tantrum. The intensity of frustration reflected aggressive behavior, such as shoving the keys or throwing or kicking the box. Protest vocalization reflected the intensity of negative vocalization intended to express opposition. The intensity of sadness expression described the amount of facial sadness expression in each epoch, whereas the presence of bodily sadness reflected the presence of some form of bodily sadness (e.g., lumping position or covering the face with the hands).

Based on the two main indicators of anger and sadness, we calculated two subdimensions of negative emotional reactivity: overall anger (i.e., facial anger, bodily anger, frustration, and protest vocalization) and overall sadness (i.e., facial sadness and bodily sadness). An overall observed negative reactivity score was formed by summing the standardized scores of the subscales. The total scores of each scale were used in the analyses. Interrater reliability was calculated for 10% of the videos, which was sufficient as follows: Cohen's $\kappa = 0.77$ for overall anger, $\kappa = 0.79$ for overall sadness, and $\kappa = 0.76$ for overall negative reactivity. The interrater

correlations were as follows: $r = 0.75–1.00$ for anger expression, $r = 0.68–0.95$ for bodily anger, $r = 0.64–0.97$ for frustration, $r = 0.42–0.98$ for facial sadness, $r = 0.56–1.00$ for bodily sadness, and $r = 0.75–0.95$ for protest vocalization.

4.3.4 Social-emotional problems and social-emotional competence in children

Children's social-emotional development at two years of age was measured using the Brief Infant Toddler Social-emotional Assessment (BITSEA), which were filled by the mothers. The BITSEA has shown to be a valid and reliable questionnaire for parents to assess toddlers' social-emotional development (Briggs-Gowan et al., 2004) in different samples. BITSEA is designed to be used with children aged 12–36 months, and it consists of 42 items. Items are scored on a scale from 0 to 2, with 0 meaning "Not true/Rarely," 1 meaning "Somewhat true/Sometimes," and 2 meaning "Very true/Often." The BITSEA problem scale comprises 31 items, with scores ranging from 0–62, whereas the BITSEA competence scale includes 11 items, with scores ranging from 0–22. In this study, the total problem and social competence scale scores were used as proxies of social-emotional development at two years old, in which the problem score measured social-emotional problems including aggression, defiance, overactivity, shyness, anxiety, and social withdrawal and the latter aspects such as compliance, empathy, and prosocial behavior. In this study we used the sum of item scores as continuous variables to reflect social-emotional problems and social-emotional competence. The Cronbach's alpha values were .59 for the competence scale and .72 for the total problem scale, which is in line with another study that evaluated social-emotional development in toddlers (Alakortes et al., 2015).

Social-emotional development at 4 years was measured with the Strengths and Difficulties Questionnaire (SDQ), which is a valid and reliable tool used to evaluate the social-emotional development of children and youth aged 3–16 years (Goodman, 1997, 2001). The questionnaire included five subscales, each with five items to measure emotional symptoms, conduct problems, hyperactivity-inattention, peer problems, and prosocial behavior. Each question was scored on a Likert scale of 0–2. The subscales (excluding the prosocial behavior subscale) were grouped into two scales: internalizing symptoms, combining the emotional symptoms and peer problems subscales, and externalizing symptoms, combining the conduct problems and Hyperactivity/Inattention subscales, as recommended for the community samples (Goodman et al., 2010). The scores of the externalizing and internalizing subscales ranged from 0–20, and the prosocial behavior subscale scores ranged from 0–10. The outcome scales in the current study were the externalizing subscale,

internalizing subscale, and prosocial behavior score, which indicates social competence. The Cronbach's alphas for these subscales varied between .56 and .73.

4.4 Statistical analyses

4.4.1 Study I

We used IBM SPSS Statistics 24 and R (R Core Team, 2018) for the analyzes. The missing values in the maternal distress variables from each time point were imputed using the package MissForest (Stekhoven & Bühlmann, 2012), and the distress values at the other measurement points were used as predictors. To scrutinize the first study question, (i.e., whether different types of distress symptoms [pre- and postnatal anxiety and depressive symptoms] have independent effects on mother–infant EA at eight months), Pearson's correlations between symptoms of depression, anxiety and pregnancy-specific anxiety and EA scales were first calculated. To investigate the effects of the timing of these symptoms, Pearson correlations between different measurement points and EA scales were computed. Next, linear regression analyses were made for those distress-EA variable pairs for which either 1) the correlation was significant based on the adjusted p value or 2) the correlation was significant only based on the unadjusted p value, but the association was theoretically interesting. The relevant subscales of maternal age, education, parity and child's sex were controlled if they correlated statistically significant with the EA subscale in question.

4.4.2 Study II

IBM SPSS Statistics (Version 26) and R (Version 3.6.3) were used to analyze the data. First, the relationships between maternal prenatal and postnatal distress, the mothers' EA, and the children's mother-reported and observed negative reactivity were assessed using Pearson's correlation coefficient. To account for the multiplicity of the tested correlations, we used permutations and the max-T method (Westfall & Young, 1993) to calculate the adjusted *p* values for these correlations. The multiplicity corrections for the mother reports of negative emotional reactivity measures and the laboratory-observed negative reactivity measures were made separately. In addition, Pearson correlations for the EA scales and the relevant subscales of the IBQ-R (distress in reaction to limitations, sadness, and frustration) and ECBQ (sadness and frustration) were calculated. In addition, the relationships between the background variables and the dependent variables were investigated using the Pearson correlation or analysis of variance (ANOVA) test.

We selected the covariates, namely maternal education, age, and parity, as well as the children's sex, based on theoretical interest and the fact that all of the covariates were correlated with some aspect or instance of the child's negative reactivity. The same covariates were placed in all models. In addition, we placed maternal prenatal and postnatal distress together with one EA scale at a time in the same models to study their independent and combined associations with child reactivity.

Regarding the moderation analyses, each model included one maternal EA scale, either prenatal or postnatal distress scores or their interactions, and the relevant covariates.

The missing values in some of the covariates and in the distress variables (1–2 in education, 1–2 in parity, 0–1 in prenatal stress, and 1–3 in postnatal stress, depending on the sample used) were imputed using the MissForest package (Stekhoven & Bühlmann, 2012).

4.4.3 Study III

The data analyses were conducted using IBM SPSS Statistics (Version 26) and R (Version 3.6.3). We started by calculating correlations between maternal EA, maternal pre- and postnatal distress, and the outcome variables of the total social-emotional problems and social-emotional competence (at two years old), externalizing and internalizing symptoms, and social competence (at four years old). In addition, the associations between the background and outcome variables were studied using Pearson's correlation or ANOVA. The associations between maternal EA at eight months and maternal pre- and postnatal psychological distress and children's social-emotional problems and social-emotional competence at two and four years were investigated with multiple linear regression models. Each model included one EA scale (4x), pre- and postnatal distress scales, and the relevant covariates of concurrent distress (at either two or four years old), child sex, and one of the outcome variables (2 at the two-year and 3 at the four-year measurement point). Child sex was selected as a covariate because it was the only background variable associated with child social-emotional problems in our sample. In addition, linear regression models were made in order to study the moderating effects of mothers' EA on the associations between maternal prenatal distress and children's social-emotional problems and social-emotional competence at two and four years old. Multiple comparison corrections were made using the Benjamini–Hochberg method (Benjamini &, Hochberg, 1995).

4.5 Ethical considerations

The Ethics Committee of the Hospital District of Southwest Finland approved the study protocol. Written informed consent was provided by the parents prior to the study visits—also on behalf of their children. The register-keeping organization gave permission to use the data drawn from national birth registries (National Institute for Health and Welfare, www.thl.fi), according to Finnish data protection legislation. All the participants were informed about the confidentiality of the study, their voluntary participation, and a right to interrupt the study visit without any specific reason.

5 Results

5.1 Associations between maternal psychological distress and mother–infant interaction (Study I)

In Study I, we examined how maternal psychological distress during the pre- and postnatal phases is associated with mother–infant interaction when the child is eight months old. Descriptive statistics for Study I are shown in table 2. Specifically, we were interested in whether depressive vs. anxiety (general and pregnancy-specific anxiety) symptoms would have unique associations with mother–infant interaction. In addition, we were interested in whether the timing of the symptoms would have some effect on mother–infant interaction.

The main associations between maternal psychological distress (ie., depressive and anxiety symptoms and maternal EA) were studied using correlational analyses. After adjusting for multiple comparisons, only the correlation between general anxiety at 34 gestational weeks and maternal intrusiveness was statistically significant (adjusted $p = .038$).

Next, linear regression models were constructed based on the statistically significant nonadjusted correlations and the theoretical value of the findings. The results are shown in table 3. We used the statistically significant correlations to select the background variables in the regression models. First, we found that higher prenatal general anxiety at gestational weeks 34 was associated with higher maternal intrusiveness after the effects of relevant confounders were controlled for. Of the background variables, only a maternal higher level of education was related to EA dimensions and, specifically, to lower intrusiveness. Pregnancy-specific anxiety symptoms did not associate with mother-infant interaction.

Table 2. Descriptive statistics for study I.

Characteristic	N = 190
EA (mean, SD)	
Sensitivity	5.3 (1.4)
Structuring	5.1 (1.5)
Nonintrusiveness	5.6 (1.5)
Nonhostility	6.1 (1.1)
Responsiveness	5.1 (1.4)
Involvement	4.9 (1.5)
EPDS (mean, SD)	
GW 14	5.1 (4.6)
GW 24	5.2 (5.1)
GW 34	5.2 (5.1)
3 months	4.6 (4.1)
6 months	5.3 (5.0)
SCL-90 (mean, SD)	
GW[a] 14	3.7 (4.5)
GW 24	4.6 (5.5)
GW 34	3.8 (5.3)
3 months	3.3 (4.2)
6 months	3.8 (5.2)
PRAQ	
GW 14	22.5 (7.2)
GW 24	22.5 (7.1)
GW 34	22.5 (6.8)

Note [a] = Gestational Weeks

Table 3. Standard linear regression model for general anxiety symptoms at gw 34 explaining maternal nonintrusiveness.

	β	S.E.	p	Partial ETA^2
Maternal age	.02	.27	.420	0.04
Mother's education				
low	-0.86	.28	.002*	0.50
middle	-0.37	.23	.114	0.14
high	0[a]	.	.	.
Primiparity	-0.37	.21	.086	0.16
Multiparity	0[a]	.	.	.
Prenatal anxiety at GW 34	-0.08	.03	.009*	0.37
Postnatal anxiety at 6 months post partum	.05	.03	.070	0.18

Note [a] = The reference group

Second, our results indicated that maternal depressive symptoms at six months predicted lower maternal structuring in the interaction after controlling for covariates. From the background variables, the mother's age was associated with structuring, with older mothers being higher in structuring than younger mothers. Third, our results indicated that postnatal depressive symptoms at six months was associated with lower child involvement of the mother after the effects of background variables were controlled for. The results are shown in Table 4.

Table 4. Standard linear regression model for maternal depressive symptoms at 6 months explaining maternal structuring and child involvement of the adult.

	β	S.E.	p	Partial ETA^2
Maternal structuring				
Mother's age	.07	.03	.009	0.36
Prenatal depressive symptoms (mean score)	.06	.03	.076	0.17
Postnatal depressive symptoms at 6 months	-0.08	.03	.007	0.38
Child involvement of the adult				
Child sex (male)	-0.36	.22	.097	0.15
Prenatal depressive symptoms (mean score)	0.23	.03	.476	0.03
Postnatal depressive symptoms at 6 months	-0.07	.03	.024	0.27

5.2 Associations between mother–infant interaction, maternal psychological distress, and child's negative emotional reactivity (Study II)

In Study II, we investigated the associations of mother–infant interaction, maternal psychological distress pre- and postnatally, and children's negative emotional reactivity in early childhood (at 12, 24, and 30 months) with two different assessment methods of negative emotional reactivity: mother reports and laboratory observations. Descriptive statistics for Study II are shown in table 5. First, the associations between the background variables and the study variables were investigated. It was shown that parity was associated with mother-reported negative reactivity at 12 months, indicating that firstborns were less reactive ($p < .05$). In

addition, the mother's age was correlated with mother reported child negative reactivity at 24 months in a way that older mothers' children were less reactive ($p < .05$). The mother's education or monthly income were not correlated with the child's negative reactivity.

Table 5. Descriptive characteristics of the sample in study II.

Characteristic	**N = 192**
EA (mean, SD)	
Sensitivity	5.3 (1.3)
Structuring	5.0 (1.5)
Nonintrusiveness	5.6 (1.5)
Nonhostility	6.1 (1.0)
EPDS (mean, SD)	
GW 14	5.0 (4.6)
GW 24	5.1 (5.0)
GW 34	5.1 (5.2)
3 months	4.3 (4.2)
6 months	5.2 (5.1)
1 year	5.3 (5.0)
2 years	5.2 (5.0)
SCL-90 (mean, SD)	
GW 14	3.6 (4.5)
GW 24	4.5 (5.5)
GW 34	3.7 (5.4)
3 months	3.0 (4.2)
6 months	3.7 (5.3)
1 year	-
2 years	3.3 (4.8)

Next, regression models were formed to investigate the simultaneous effects of the EA and maternal psychological distress on child outcomes. It was shown that maternal sensitivity was independently associated negatively with mother-reported child negative emotional reactivity at 24 months after controlling for the effects of pre- and postnatal psychological distress and covariates. In addition, postnatal psychological distress was positively associated with negative reactivity at 12 and 24 months after controlling for the effects of covariates, maternal sensitivity, and prenatal psychological distress. Prenatal psychological distress was not associated with negative reactivity at 24 months after controlling for the effects of maternal EA, postnatal distress, or relevant covariates. The results are shown in table 6.

Table 6. Linear Regression Model for Maternal Sensitivity, Pre- and Postnatal Distress explaining Mother-Reported Child Emotional Reactivity at 24 Months.

	β	S.E.	p	Partial ETA^2	95 % CI
Mothers age	-0.02	0.01	.108	0.02	[−0.04, 0.00]
Education					
Middle[b]	0.09	0.13	.480	0.01	[−0.16, 0.35]
High[c]	0.02	0.13	.860		[−0.23, 0.27]
Sex	0.05	0.09	.553	0.00	[−0.12, 0.23]
Parity	-0.03	0.09	.746	0.00	[−0.21, 0.15]
Prenatal Distress	-0.04	0.07	.532	0.00	[−0.17, 0.09]
Postnatal Distress	0.24	0.07	.000**	0.11	[0.11, 0.37]
Sensitivity	-0.08	0.03	.024*	0.05	[−0.15, −0.01]

Note. a Part of secondary or secondary school. b High school or vocational school. c University/polytechnics or higher. * p < .05. * * p < .01.

Furthermore, it was shown that higher maternal structuring was negatively associated with mother-reported child negative reactivity at 24 months after controlling for maternal pre- and postnatal psychological distress and covariates. Maternal postnatal psychological distress was also positively associated with child negative reactivity at 24 months after controlling for the other factors. Maternal prenatal distress was not associated with children's negative emotional reactivity. The results are shown in Table 7. We did not find any associations between maternal EA, maternal psychological distress, and a laboratory-observed child's negative emotional reactivity.

Table 7. Linear Regression Model for Maternal Structuring, Pre- and Postnatal Distress, and Mother-Reported Emotional Reactivity at 24 Months.

	β	S.E.	p	Partial ETA^2	95 % CI
Mothers age	-0.02	0.01	.192	0.02	[−0.04, 0.01]
Education					
Middle[b]	0.07	0.13	.571	0.01	[−0.18, 0.32]
High[c]	0.00	0.12	.998		[−0.25, 0.25]
Sex	0.07	0.09	.446	0.01	[−0.11, 0.24]
Parity	-0.03	0.09	.715	0.00	[−0.21, 0.15]
Prenatal Distress	-0.03	0.07	.654	0.00	[−0.16, 0.10]
Postnatal Distress	0.23	0.07	.001**	0.10	[0.10, 0.37]
Structuring	-0.07	0.03	.021*	0.05	[−0.13, −0.01]

Note. a Part of secondary or secondary school. b High school or vocational school. c University/polytechnics or higher. * p < .05. * * p < .01.

5.3 Associations between mother–infant interaction, maternal psychological distress and children's social-emotional development (Study III)

Descriptive statistics for Study III are shown in table 8.

Table 8. Descriptive statistics of the study variables in study III.

Characteristic	N = 127 (at 2 years)	N = 94 (at 4 years)
EA (mean, SD)		
Sensitivity	5.3 (1.4)	5.3 (1.2)
Structuring	5.1 (1.5)	5.1 (1.5)
Nonintrusiveness	5.8 (1.3)	5.7 (1.4)
Nonhostility	6.2 (1.0)	6.2 (1.0)
EPDS (mean, SD)		
GW[a] 14	4.6 (4.3)	4.2 (3.8)
GW 24	4.6 (4.6)	4.1 (4.0)
GW 34	4.5 (4.6)	4.2 (4.2)
3 months	4.0 (3.9)	3.9 (3.7)
6 months	4.5 (4.7)	4.3 (4.3)
1 year	5.0 (4.6)	4.8 (4.6)
2 years	4.8 (4.5)	4.6 (4.4)
4 years	4.1 (4.1)	4.3 (4.2)
SCL-90 (mean, SD)		
GW 12	3.1 (4.3)	2.6 (3.4)
GW 24	3.7 (4.9)	3.3 (4.5)
GW 34	3.2 (4.6)	2.8 (4.1)
3 months	2.6 (3.8)	2.5 (3.7)
6 months	3.0 (4.6)	2.8 (4.4)
2 years	3.3 (4.3)	3.0 (4.1)
4 years	3.1 (4.6)	3.3 (4.6)

Note [a] = Gestational weeks

In Study III, linear regression models were formed to investigate the combined associations between mother–infant interaction, maternal psychological distress, and children's social-emotional outcomes. The results are seen in Table 9. We found that initially, sensitivity and structuring were negatively associated with toddler's social-emotional problems. After the multiple comparison corrections, only the association between maternal structuring and children's social-emotional problems remained statistically significant. The more structuring the mother was, the less social-emotional problems the children showed. Association for sensitivity did not

survive corrections for multiple comparisons, hence only the results for structuring are shown in the table.

Table 9. Linear regression model for the effects of maternal structuring on children's social-emotional problems at two years.

	β	S.E.	p	Partial ETA^2	95% CI	ADJUSTED p
Child sex	-0.09	0.15	.545	0.00	[-0.39; 0.21]	
Prenatal distress	0.01	0.11	.898	0.00	[-0.21¸0.24]	0.963
Postnatal distress	0.50	0.14	>.001**	0.09	[0.21; 0.78]	0.005*
Current distress	0.03	0.13	.837	0.00	[-0.23; 0.28]	
Structuring	-0.20	0.07	.007**	0.06	[-0.35; -0.06]	0.042*

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

We did not find any association between maternal EA and maternal psychological distress and children's social-emotional problems at four years.

Regarding children's social competence, we found that maternal sensitivity was positively associated with children's social competence at two years. The results are shown in table 10.

Table 10. Linear regression model for the effects of maternal sensitivity on children's social competence at two years.

	β	S.E.	p	Partial ETA^2	95% CI	ADJUSTED p
Child sex (girl)	0.33	0.16	.042*	0.03	[0.01; 0.66]	
Prenatal distress	-0.12	0.12	.312	0.01	[-0.36¸0.12]	0.500
Postnatal distress	-0.22	0.15	.156	0.02	[-0.52; 0.08]	0.380
Current distress	-0.05	0.14	.723	0.00	[-0.32; 0.22]	
Sensitivity	0.21	0.08	.011*	0.05	[0.05; 0.36]	0.042

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

We did not find any associations between other dimensions of EA and children's social-emotional competence at two or four years.

5.4 The moderating effects of mother–infant interaction on the associations between maternal psychological distress and children's negative emotional reactivity and social-emotional development (Studies II and III)

In Studies II and II, we were interested in investigating whether the mother–infant interaction (i.e., mother's EA) has moderation effects on the associations between maternal psychological distress and children's negative emotional reactivity (Study II) or children's social-emotional outcomes (Study III). Regarding the associations between maternal psychological distress and children's negative emotional reactivity, we did not find any moderation effects concerning any EA subscales for these associations. Concerning the results of the moderative effects between the associations between maternal distress and children's social-emotional outcomes (Study III), we found that in the initial models (before multiple comparison corrections), maternal sensitivity moderated the association between prenatal distress and children's internalizing and externalizing symptoms at four years old, meaning that greater maternal sensitivity appeared to attenuate the association between maternal prenatal distress symptoms and children's social-emotional problems. Maternal structuring also moderated the association between maternal prenatal distress and children's internalizing symptoms at four years old; the more structured the mother, the weaker the positive association between maternal prenatal distress and internalizing symptoms in children at four years old. In addition, maternal nonhostility moderated the association between maternal prenatal distress and children's internalizing symptoms at four years old. Conversely, the less hostile the mother, the weaker the positive association between maternal prenatal distress and internalizing symptoms in children at four years old. However, after multiple-comparison corrections, none of the moderation analyses remained statistically significant, and no other moderation effects were detected.

6 Discussion

The aims of this study were to assess 1) the association between maternal pre- and postnatal psychological distress and mother–infant interaction, 2) the effects of mother–infant interaction and maternal pre- and postnatal psychological distress on children's negative emotional reactivity and 3) the effects of mother–infant interaction and maternal pre- and postnatal psychological distress on children's social-emotional development and, 4) the moderating effects of mother–infant interaction on the associations between maternal psychological distress and child development.

We found that higher prenatal anxiety symptoms during late pregnancy were associated with maternal intrusiveness at eight months. Postnatal maternal depressive symptoms associated with maternal structuring and children's involvement of the adult at eight months of the child's age. We also found that higher maternal sensitivity and structuring at 8 months after birth were associated with children's lower negative emotional reactivity at 24 months. In addition, we showed that higher maternal structuring was associated with a lower level of social-emotional problems in children at 24 months. Higher maternal sensitivity was associated with a better social-emotional competence in children at 24 months. Maternal postnatal, but not prenatal psychological distress, was associated with children's mother-reported negative emotional reactivity at 24 months and social-emotional problems and competencies at 24 months.

6.1 Maternal psychological distress and mother–infant interaction

One of the main findings of this study was that higher maternal prenatal anxiety symptoms in late pregnancy associated with higher maternal intrusiveness at eight months of child age, and higher maternal postnatal depressive symptoms at six months were associated with lower maternal structuring and child involvement of the adult (Study I). The result that maternal prenatal anxiety symptoms associated with mother–infant interaction is partly in line with our hypothesis and earlier studies that have shown that prenatal maternal psychological distress might be associated

with mother–infant interaction such as lower sensitivity and lower responsiveness of the mother after birth (Flykt, 2010; Kemppinen et al., 2006). One earlier study showed that prenatal anxiety symptoms were associated with higher maternal control (i.e., intrusiveness) (Parfitt et al., 2013) as was also found in our study. Hence our results support the view that prenatal maternal distress might associated with mother-infant interaction. The association between maternal prenatal anxiety symptoms and maternal intrusiveness after birth might be explained by interruptions in psychological preparation during the transition to parenthood due to maternal psychological distress (Brockington et al., 2006; Pearson et al., 2012). In addition, it has been shown that maternal anxiety symptoms might alter the neurocognition of the mother in late pregnancy. Increased anxiety symptoms might increase the accuracy of encoding negative emotional facial expressions in infants (Pearson et al., 2009). This process is thought to serve as an evolutionary protective system, serving infant security against outside threats. On the other hand, this might be harmful for the quality of mother–infant interaction—if the mother sees non-existing threats in the environment due to her hypervigilant negative emotion processing. Enhanced coding of an infant's negative emotional expressions might lead to intrusive behavior on the mother's side, as she is trying to protect the infant from nonexisting threats.

In addition, the finding that maternal postnatal depressive symptoms are associated with maternal EA, especially maternal structuring, is in line with earlier studies (Easterbrooks et al., 2012; Kluczniok et al., 2018). It has been shown that maternal depressive symptoms are associated with mother–infant interaction, including maternal sensitivity and structuring, (Easterbrooks et al., 2000) as well as, for example, higher hostility and higher disengagement from the child (Lovejoy et al., 2000). These effects can also be seen in subclinical samples (Behrendt et al., 2016), which is in line with our own low-risk sample. Here again, one explanation might be that depressive symptoms have been shown to be associated with altered emotional processing (Snyder et al., 2015), impaired emotional responsiveness, and executive functioning of adults (Castaneda et al., 2008; Drevets, 2001) and might hence diminish the mother's capability to detect the infant's subtle initiatives in the interaction, leading to compromised structuring of the interaction situations. It has been shown that cognitive distortions related to depressive symptoms are associated with a lower sensitivity of mothers related to impaired perspective taking of the infant's interactive behavior (Trapolini et al., 2008). Another explanation could be that the preparation, both conscious and unconscious, for motherhood might be interrupted by maternal distress during pregnancy and early postpartum period (Pearson et al., 2012). The neuroaffective alterations that occur in pregnancy, which prepare the mother to be more sensitive in the interaction might be interrupted, but the mother could also have less energy to read or attend the well-baby clinics and other services that are meant to help the parent have more knowledge about the

development of the baby and might hence enhance adequate structuring of the different everyday situations (Pearson et al., 2012).

The finding that maternal depressive symptoms after birth are associated with infant's EA, namely involvement of the adult, is also in line with our hypothesis and previous studies (Porreca et al., 2018). Links between maternal executive functioning and maternal and child EA have been found in earlier studies, which might explain effects of the depressive symptoms on child EA (Porreca et al., 2018). Higher maternal depressive symptoms are suggested to be associated with impaired neuropsychological functioning of the infant following the lower sensitivity and responsiveness of the mother. EA is viewed as a dyadic emotional relationship that develops in interactions in reciprocal ways (Biringen et al., 2014; Harris et al., 2021). EA theory views interaction as a dyadic process in which the "other can not look good without the other." This means that in dyads where the maternal side of the EA is compromised, the child's interactional EA might also be compromised.

6.2 Mother–infant interaction and children's negative emotional reactivity and social-emotional development

Another main finding of this study was that higher maternal sensitivity and structuring longitudinally associated with lower negative emotional reactivity at 24 months of child age (Study II). This finding is in line with previous studies that show associations between higher-quality mother–infant interaction and lower negative emotional reactivity (Freund et al., 2019; Paulussen-Hoogeboom et al., 2007). The results are also consistent with studies showing associations between higher maternal EA and lower infant negative reactivity (Korja & McMahon, 2021). Studies have shown that a higher quality of caregiving is associated with better self-regulation in children (Frick et al., 2018; Little & Carter, 2005). Earlier studies have shown the role of parental structuring in enhancing children's emotion regulation (Norona & Baker, 2017). As parental structuring and sensitivity aim to set age-appropriate limits for the child (Biringen et al., 2014) and help them to control anger and frustration in different every day life situations through co-regulation of the emotions provided by the parents (Bibok, & Carpendale., 2009; Tronick & Gianino, 1986), the toddler is able to embrace different strategies to modulate the emotional reactions. Through the external regulation of the mainly automatic emotional reactions provided by the emotionally sensitive and structuring parent, the child might appear less emotionally reactive (Frick et al., 2018; Tronick & Gianino, 1986). Our results showed an association between maternal sensitivity and structuring during infancy and negative emotional reactivity in toddlerhood, but not infancy. This might indicate that maternal caregiving behavior has long-term effects on a child's emotional reactivity,

which do not emerge before toddlerhood when the child's basic reactivity is more stable than in infancy. Developmentally, it also seems plausible that the role of structuring might be emphasized during toddlerhood. As a child becomes more independent and active in the environment but still relies heavily on the external co-regulation of emotions provided by the parents, the parental ability to structure the environment probably plays a more important role in diminishing the child's negative emotions (Bibok et al., 2009).

Concerning the effects of mother–infant interaction on children's social-emotional development, the main finding was that higher maternal structuring was associated with a lower amount of social-emotional problems in children at 24 months. This is in line with previous research that found maternal EA, such as lower sensitivity, to be associated with children's heightened depressive symptoms and behavioral problems in middle childhood (Easterbrooks et al., 2012). It is also in line with previous findings that maternal structuring, such as limit setting and enhanced reading and talking to the child, supports the child's social competence at three years (LeCuyer & Houck, 2006) and decreases behavioral problems in middle childhood (Mendelsohn et al., 2018). From a developmental perspective this is plausible. Emotion regulation is enhanced in the context of early mother–child interaction (Behrendt et al., 2019), and self-regulation capacity is linked with lower emotional reactivity and fewer social-emotional problems (Behrendt et al., 2019, 2020; Spinrad et al., 2007). As toddlers become more autonomous and move increasingly in the environment, the need for maternal limit-setting and providing age-appropriate stimuli in the environment increases in order to keep the toddler safe. Limit-setting and structuring of everyday life situations also provide an environment where social rules and ways of modulating one's behavior are modeled consistently (LeCuyer & Houck, 2006). This is also assumed to enhance the toddler's self-regulation capacity through the co-regulation of the emotions (Bernier et al., 2010; Tronick & Gianino, 1986), which, in turn, has shown directly to be associated with fewer social-emotional problems even in adolescence (Clark et al., 2002), starting during early childhood (Riggs et al., 2006).

Our finding, considering the effects of higher maternal sensitivity on a child's better social-emotional competence at 24 months, is also in line with previous research and with our hypothesis. It has been shown that maternal sensitivity is associated with fewer behavioral problems in children at 24 and 36 months and better social competence at 24 months (Leerkes et al., 2009). In addition, maternal structuring has been shown to be associated with children's better social competence in early childhood (Lengua et al., 2007). Children's self-regulatory capacity is enhanced through high-quality parenting, which, in turn, is associated with better social competence in children (Eisenberg et al., 2015). Children learn social norms and adaptive social behaviors through highly sensitive and structured parenting

(Lengua et al., 2007; Spinrad et al., 2007) and hence the child is able to adopt socially competent behavior.

Contrary to earlier research (Eisenberg et al., 2015; Elam et al., 2014; Klein et al., 2018) and our hypothesis, we did not find any associations between maternal nonintrusiveness and maternal nonhostility and children's negative emotional reactivity or social-emotional development. Based on the results it might be that in low-risk samples such as ours, maternal sensitivity and structuring play a more important role in the early development of children. Another explanation might be that the variation in the scales, such as nonhostility, was lower in our low-risk sample; hence, we were unable to detect any such effects.

6.3 Maternal psychological distress and children's negative emotional reactivity and social-emotional development

Considering the effects of maternal psychological distress pre- and postnatally, the main finding was that maternal postnatal psychological distress was associated with children's heightened negative emotional reactivity at 12 and 24 months as well as with children's increased social-emotional problems at 24 months after the effects of prenatal distress, concurrent distress and mother-infant interaction were taken into account (Studies II and III). These findings are, to some extent, in line with earlier studies showing associations between maternal psychological distress and these developmental outcomes in children. It has been shown that postnatal maternal distress, including both depressive and anxiety symptoms, is associated with negative emotional reactivity in children (Field, 2010, 2018) as well as with social-emotional difficulties, such as externalizing and internalizing, in children (Rees et al 2009, Hentges 2019). Our results provide more evidence for the detrimental effects of postnatal maternal psychological distress in comparison to prenatal effects. Some studies have shown that maternal distress during later phases of child development, such as toddlerhood, affects child development more (Hentges et al., 2020). Our results are contradicting this view, as in our studies, the early postnatal symptoms had the most effects in comparison to prenatal and concurrent maternal distress. As maternal psychological distress might affect mother–infant interaction in the form of lower sensitivity (Field, 2010) and structuring (Easterbrooks et al., 2000), child development might be compromised through a lower quality of caregiving. The negative effects of maternal psychological distress might be the result of cognitive distortions related to both anxiety and depressive symptoms, which lead to lower-quality caregiving because the parent's ability to sensitively detect the cues of the infant might be more difficult (Pearson et al., 2012). As the mother–infant interaction and postnatal maternal distress both showed independent effects on children's

negative emotional reactivity and social-emotional problems in our study, there seems to be also factors other than mother–infant interaction quality explaining these associations. One possible explanation is the genetic transmission of maternal psychological distress to children's social-emotional problems, such as internalizing. In addition, in the case of maternal depression, it might be that the physical environment of the infant/toddler is less stimulating in other aspects than interaction, as the mother might have less energy to provide different social and play stimuli for the baby.

Contrary to our hypothesis and findings from other studies, which have found that prenatal distress increases children's negative emotional reactivity and social-emotional problems in children (Hentges et al., 2020; Korja et al., 2017; Madigan et al., 2018), we did not find any associations between prenatal maternal psychological distress and children's development after the effects of maternal EA and maternal postnatal distress were taken into account. The discrepancy in the results might be explained by the fact that not all studies have simultaneously investigated the effects of parenting or both pre- and postnatal maternal distress (Thomas et al., 2017). Based on their systematic review, Kingston et al. (2012) suggested, that prenatal psychological distress can have an adverse effect on cognitive, behavioral, and psychomotor development, whereas postnatal distress contributes mainly to cognitive and social-emotional development in children. These findings are partially in line with our study, as we found that postnatal maternal psychological distress was associated with children's social-emotional developent, whereas prenatal distress was not. On the other hand, in our study, maternal postnatal psychological distress (vs. prenatal distress) was also associated with children's behavioral outcomes (i.e., negative emotional reactivity). Our findings support the view that maternal EA and postnatal maternal psychological distress might play a more important role on children's social-emotional development in a low-risk sample where the level of prenatal maternal distress is fairly low. It is also possible that in the case of a low-risk sample such as ours, the relatively high EA mother–infant interaction diminished that associations between prenatal distress and child developmental outcomes.

6.4 Moderative effects of mother–infant interaction on the associations between maternal psychological distress and child outcomes

Contrary to our hypothesis and findings from previous studies (Bergman et al., 2008; Grande et al., 2022; Kaplan et al., 2008b; Thomas et al., 2017; Wurster et al., 2020), we did not find any evidence for the moderating effects of mother–infant interaction on the associations between maternal psychological distress and children's negative

emotional reactivity or social-emotional development. On the other hand, this is partially in line with other studies that have not found any moderative effects of mother–infant interaction on the associations between maternal psychological distress and child negative emotional reactivity (Korja & McMahon, 2021). It might be that in our sample with fairly low amounts of maternal psychological distress, the statistical power was not sufficient to detect such associations. Another possible reason why we failed to detect such moderation effects might be that according to some studies, the moderation effects could only be detected in case of chronic and clinical levels of maternal psychological distress (Keller et al., 2005; Milan et al., 2009). It may also be that the effects of maternal distress and mother–infant interaction are independent and affect child development through different routes. Mother–infant interaction is thought to affect children's social-emotional development through impaired sensitivity and other aspects of interaction.

6.5 Strengths and limitations of the study

A major strength of our study is its longitudinal study design, which enabled us to assess the same families from pregnancy onwards until the children were four years old. Another strength is that we used laboratory assessments as well as questionnaires assessing maternal and child factors. In addition, one strength is that we were able to measure maternal psychological distress at various measurement points, which gave us the opportunity to compare the effects of maternal psychological distress pre- and postnatally and to control for the effects of concurrent symptoms (Study II and III). We were also able to assess the effects of the timing of maternal distress during pregnancy (gestational weeks 14, 24, and 34; Study I) and early postpartum (3 and 6 months) on mother–infant interaction. Another strength was that children's negative emotional reactivity was measured at various measurement points and with different measurements (mother reports and laboratory observations). In addition, maternal and child EA was measured with laboratory observations, which are assumed to be more reliable in comparison to mother-reports of mother–infant interaction quality.

There are also limitations in our study. One limitation of the study might be that the only statistically significant results concerning the associations between mother–infant interaction and maternal psychological distress and children's negative emotional reactivity were found using maternal reports of infant and toddler temperament. Concerns about the objectivity have been raised, as the assessment might be influenced by mothers' subjectivity or there might be social desirability in the answers (Gartstein & Rothbart, 2003). In addition, maternal depressive symptoms might bias the way mothers rate their children's negative emotional reactivity (Leerkes & Crockenberg, 2003). However, the instruments to assess infant

and toddler temperament in this study were developed to assess concrete behavior during the past week, instead of an overall view of infant/toddler behavior (Gartstein & Rothbart, 2003) which better captures the "real" infant/toddler behavior instead of an overall view of the parent about the child. The temperament questionnaires that were used in the study (IBQ-R and ECBQ) are very widely used and reliable instruments (Gartstein & Rothbart, 2003; Putnam et al., 2006, 2014). Another limitation of the study is that the internal consistency of the BITSEA and SDQ questionnaires was fairly low. On the other hand, these instruments are widely used and have shown adequate or satisfactory reliability in other normative samples (Croft et al., 2015; Karabekiroglu et al., 2010; Smedje et al., 1999; Stone et al., 2015). Furthermore, in another Finnish sample that used the BITSEA, internal consistencies were fairly low (Alakortes et al., 2015)

Moreover, maternal psychological distress was measured only with self-reports and not with clinical assesment tools. However, using self-reports is a common method in studies in the same area (Stein et al., 2014). In addition, one might consider as one limitation that the amount of maternal psychological distress was fairly low, as can be expected in a non-risk sample, such as ours. Still, it is also of interest to study normal populations, to gain more knowledge on the possible effects of lower levels of maternal psychological distress on child development. In this way, interventions aimed at preventing the possible harmful outcomes of compromised mother–infant interaction and maternal psychological distress on child development can be better targeted in society. In addition, one limitation of this study is that we were not able to assess mother–infant interaction at the same time that children's social-emotional outcomes were measured. This might have given us more information on how mother–infant interaction is associated with child outcomes at the same time points vs. only when measured at infancy. It must be noted that the directions of the associations between maternal caregiving behavior and children's negative emotional reactivity and social-emotional development are multidirectional, as studies show that negative emotional reactivity enhances negative parenting styles (Paulussen-Hoogeboom et al., 2007). This was not assessed in our study, so caution with interpretation of the directions must be kept. Finally, we were unable to control for the effects of possible genetic transmission of the social-emotional symptoms on the children in this study. In addition, the utilization of brain imaging would be helpful in future studies to gain more knowledge about the brain mechanisms behind the mechanisms of mother–infant interaction and maternal psychological distress on children's social-emotional development. It should also be noted that the generalization of the results could be culture-specific and not necessarily generalizable to other cultures.

6.6 Clinical implications of the study and future research

Our results have several clinical implications. Our results show that the quality of mother–infant interaction and maternal postnatal psychological distress are associated with negative emotional reactivity in children as well as with their social-emotional development during early childhood. This supports the view that interventions targeting both parenting and maternal psychological distress are important in potentially reducing the negative effects of these on children's emotional reactivity and broader social-emotional development in children in early childhood. Negative emotional reactivity in early childhood is associated with later psychopathology such as ADHD and externalizing (Frick et al.); it is an important target of intervention. As social-emotional problems in early childhood tend to predict psychopathology later in life (Briggs-Gowan et al., 2004), it is very important to target them in interventions early enough to reduce social-emotional problems later in life on a larger scale. As up to 25 % of children show some degree of social-emotional difficulties early in life (Alakortes et al., 2015; Briggs-Gowan et al., 2001), problems in children's social-emotional development are a big societal burden from a humane and financial perspective.

In the case of prenatal maternal psychological distress, the interventions would be useful to start during pregnancy to prevent the possible harmful effects of prenatal maternal distress on child development, which many other studies have shown (Field, 2017a, 2017b; Korja et al., 2017). Maternal symptoms of anxiety and depression can be treated successfully (Field, 2018; O'Hara & Mc Cabe, 2013) already prenatally (Cauli et al., 2018; Doyle et al., 2009). As mother–infant interaction patterns show some stability over time (Else-Quest et al., 2011; Holmberg et al., 2022), it would be beneficial to assess mother–infant interactions, especially in the case of maternal psychological distress during infancy, in order to detect the dyads at risk. This is most effectively done in maternity clinics and well-baby clinics, where the families' overall health is assessed during the perinatal period. To do this, the resources in these healthcare units should be maintained. Studies show that parenting quality interventions are beneficial starting from infancy, since maladaptive patterns of mother–infant interaction are more easily affected before they become established (Coo et al., 2018; Gross et al., 2003), and the interventions should be initiated as early as possible to avoid the potentially harmful effects of prenatal distress and compromised mother–infant interaction on children's social-emotional problems and, for example, neuropsychiatric disorders. As investigating and intervening in these problems cost a lot, providing the interventions early enough would be more cost-effective for society. Changes in improving maternal sensitivity can be seen even when using a-few-session interventions (Bakermans-Kranenburg et al., 2003; McConnell et al., 2020). Through the changes in maternal behavior by

enhanced sensitivity and overall EA the problems in children's social-emotional development can be reduced through enhanced self-regulation in children (Eisenberg, Vidmar, et al., 2010; Lengua et al., 2007; McConnell et al., 2020). Interventions targeting at reducing maternal psychological distress and simultaneously enhancing maternal sensitivity might be the most beneficial and cost-effective (Coo et al., 2018; Salo et al., 2019). Studies have shown that children's negative emotional reactivity might exacerbate negative parenting styles (Paulussen-Hoogeboom et al., 2007). As suggested by earlier studies, these associations are multidirectional; hence, they would be an important aspect of future research. More studies are also needed with older children to enhance the understanding of the longitudinal effects of mother–infant interaction on children's social-emotional development.

7 Conclusions

Our results highlight the role of multiple areas of mother–infant interaction, namely maternal sensitivity and structuring in affecting children's negative emotional reactivity and social-emotional development. This highlights the importance of using interventions that aim to affect these different aspects of mother–infant interaction, such as Nurture and Play (Salo et al., 2019), which is based on the EA theory and includes the different interactional aspects as targets of intervention. Mothers with higher EA are able to read the infant's subtle interactional cues more easily, thus providing better external supportive co-regulation of infant emotions and, therefore, enhancing the young child's self-regulation capacity. This might reduce social-emotional problems in children. As Nurture and Play-intervention also focuses on reducing maternal depressive symptoms, it might be one of the most cost-effective interventions in maternity healthcare practices and family counseling centers in Finland.

Against our expectations and some earlier studies (Korja et al., 2017; Madigan et al., 2018; Van den Bergh et al., 2020), we did not find associations between prenatal maternal psychological distress and children's negative emotional reactivity or social-emotional problems, or social-emotional competencies after the effects of postnatal distress and mother–infant interaction were taken into account. Hence, in our non-clinical sample postnatal maternal distress associated with child development more than prenatal distress. Still, as prenatal distress has shown to associate with children negative reactivity and social-emotional development and also might predict postnatal psychological distress (Glover & Capron, 2017; Korja et al., 2017), it is important to screen the symptoms starting from pregnancy. Traditionally, depressive symptoms have been screened more systematically in maternity clinics, but our results highlight the importance of screening also anxiety symptoms. Contrary to our expectations and earlier studies (Endendijk et al., 2017; Frigerio & Nazzari, 2021), we did not find evidence for the moderating effects of mother–infant interaction on the associations between prenatal psychological distress and child outcomes. It seems that in our non-risk sample, with the amount of maternal psychological distress being fairly low in these dyads, the postnatal

factors including both mother–infant interaction and postnatal distress exceeded the effects of prenatal distress.

It is vital to provide the interventions early enough to change the early emerging and somewhat stable patterns of mother–infant interaction to prevent problems in children's social-emotional development (Else-Quest et al., 2011). Since treating social-emotional problems later in life is expensive, it is very important to provide resources in maternity and well-baby clinics so that dyads in need of help can be supported early enough.

Abbreviations

ANOVA	Analyses of Variance
BITSEA	The Brief Infant Toddler Social Emotional Assesment
CNS	Central Nervous system
EC	Effortful control
ELS	Early Life Stress
EA	Emotional Availability
EAS	Emotional Availability Scales
EPDS	The Edinburgh Postnatal Depression Scale
GCS	Glucocorticoids
HPA	Hypothalamic Pituitary Adrenocortical Axis
Lab Tab	The Preschool Laboratory Temperament Assessment Battery
SCL-90	The symptom Checklist
SDQ	The Strengths and Difficulties Questionnaire

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