Research article

Maternal substance use disorder predicting children's emotion regulation in middle childhood: the role of early mother-infant interaction

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A B S T R A C T

Background: Maternal prenatal substance use disorder (SUD) represents a dual risk for child wellbeing due to teratogenic impacts and parenting problems often inherent in SUD. One potential mechanism transferring this risk is altered development of children's emotion regulation (ER). The present study examines how mother's prenatal SUD and early mother-infant interaction quality predict children's ER in middle childhood.
Method: The participants were 52 polysubstance using mothers and 50 non-users and their children. First-year mother-infant interaction quality was assessed with the Emotional Availability (EA) Scales and children's ER with the Children's Emotion Management Scales (CEMS), and its parent version (P-CEMS) at 8–12 years.
Results: Mother's prenatal SUD predicted a low level of children's adaptive ER strategies, whereas early mother-infant interaction problems predicted a high level of emotion dysregulation. The dyadic interaction also mediated the effect of SUD on emotion dysregulation. In the SUD group, more severe substance use predicted high emotion inhibition.
Conclusion: Early mother-infant interaction quality is critical in shaping children's ER, also in middle-childhood. Interventions aimed for mothers with prenatal SUD should integrate parenting components to support the optimal development of multiply vulnerable children.

1. Introduction

Learning to express and regulate emotions is a crucial developmental task in early childhood. Emotion regulation (ER) refers to children's extrinsic and intrinsic ways to monitor, evaluate and modify the duration, intensity and expression of emotional reactions, for instance, by cognitively reappraising a distressing situation or suppressing painful emotions (Gross, 2013; Thompson, 1994). Effective ER, characterized by compatibility with environmental demands, contributes to optimal social and cognitive development and good mental health (Eisenberg et al., 2010; Gross and Jazaieri, 2014). Therefore, it is important to learn about preconditions for children's ER in families at risk.

Mother's prenatal substance use disorder (SUD) can form a dual risk for the development of ineffective ER in children. First, prenatal substance exposure is associated with structural and functional alterations in the fetal brain, such as connectivity between the ventral prefrontal cortex and the amygdala, which may affect the children's capacity to regulate

emotions, attention, and behavior (Ross et al., 2015; Thompson et al., 2009). Second, mothers with SUD often show problematic co-regulatory skills in the early mother-infant interaction, such as inability to soothe infant distress (Beeghly and Tronick, 2011) and difficulties in recognizing infants' emotional responses (Suchman et al., 2010), that are critical for the development of children's ER.

Research confirms harmful effects of maternal prenatal cocaine or amphetamine use on infants' and toddlers' ER (Frank et al., 2001; LaGasse et al., 2012). Longitudinal studies are important, first, because children's dormant ER problems may become more visible later in school age due to maturational processes and increased demands for academic skills and socioemotional competences in peer relationships (Beeghly and Tronick, 2011; Buckingham-Howes et al., 2012; Eisenberg et al., 2010; Rydell et al., 2007). Second, prenatal exposure to maternal substance use can underlie subtle biological changes that emerge as neurobehavioral problems only during later child development or under stressful life circumstances (Beeghly et al., 2003; Kaltenbach, 2013).

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However, a majority of studies among school-age children of mothers with SUD have focused on behavioural and cognitive regulation problems, such as aggression, withdrawal, and deficits in executive functioning (EF) (Ackerman et al., 2010; Lester and LaGasse, 2010), thus ignoring developmentally salient and dynamic ER strategies, such as reappraisal and suppression, that children use to manage their emotional experiences in increasingly complex social environments.

The current study contributes to the literature by examining the effects of maternal prenatal SUD, characterized by polysubstance use, on developmentally salient regulation of specific emotions of sadness and anger in middle childhood. It further examines whether the quality of early mother-infant interaction mediates the impact of maternal SUD on children's later ER.

1.1. Maternal substance use and children's emotion regulation

Children prenatally exposed to maternal substance use have heightened risks for early cognitive, sensorimotor, and social-emotional problems (Conners et al., 2004; Salo and Flykt, 2013; Smith et al., 2015). These, and especially ER problems are known to be transdiagnostic risk factors for mental health problems (Gross and Jazaieri, 2014).

Maternal prenatal SUD increases infants' ER problems that typically emerge as soothing difficulties, inflexible and narrow repertoire of stress regulation, high physical reactivity, and negative emotionality, evidenced among children exposed to cocaine (Eiden et al., 2009; Mayes et al., 1996), cannabis and tobacco (Eiden et al., 2018), and methamphetamine (LaGasse et al., 2012; Smith et al., 2015). Neonatal abstinence syndrome is common among newborn exposed to opioid drugs and relates to irritability and high-pitched crying that are also indicators of ER problems (Fodor et al., 2014). Further, toddlers exposed to stimulants showed heightened emotional reactivity, internalizing symptoms, and EF problems, especially in inhibitory control (Abar et al., 2013; Kiblawi et al., 2013; LaGasse et al., 2012; Richardson et al., 2009).

Concerning middle childhood, prenatal cocaine exposure is found to increase EF problems of impulse control, attention and memory, and externalizing symptoms (Ackerman et al., 2010). Prenatally cocaine-exposed adolescents showed similar ER problems (Lester and LaGasse, 2010), and difficulties in soothing stress-related arousals (Chaplin et al., 2010). Research thus suggests that prenatal substance exposure can hinder ER-relevant cognitive development, including EF, and increase negative emotions of anxiety, depression, and aggression in middle childhood. With increasing social experiences and improved cognitive skills, children begin to use more complex ER strategies and rely less on regulatory help from their parents (Thompson and Goodman, 2010; Salisch, 2001). In contrast to infants and toddlers, children in middle childhood are able more accurately to identify and verbally report their mental efforts to regulate emotions. It is informative to learn about the impact of maternal SUD on specific developmentally salient ER strategies that children typically use in middle childhood to manage significant feelings, especially sadness, anger, and fear (Zimmermann and Iwanski, 2014).

While there is no consensus on the number and content of ER strategies, much developmental research has focused on the following three ER dimensions (Compas et al., 2001; Eisenberg et al., 2005; Zeman et al., 2002): First, *emotion dysregulation* refers to heightening of one's negative emotions and expressing them in an unregulated, culturally inappropriate manner. It may indicate the lack of efficient "top-down" regulation of emotions (e.g., based on cortical brain regions) resulting from excessive responsivity of the threat detection and emotion generating systems (e.g., amygdala and limbic areas) (Öner, 2018). Second, *adaptive emotion regulation* refers to efficient use of constructive emotion regulation strategies (e.g., cognitive reappraisal or framing). These strategies help children successfully match their own emotions with their salient personal goals and situational demands (Gross and Jazaieri, 2014). Third, *emotion inhibition* refers to hiding and suppressing one's emotional experiences and expressions. Such strategy can help maintain functional

social interactions in important situations, thus reflecting cultural and developmental maturity (Kobylinska and Kusev, 2019). Yet, excessive emotion inhibition can reflect interpersonal mistrust and fear for others' disapproval of genuine emotion expressions (Zimmer-Gembeck et al., 2017), which can associate with psychopathology (Aldao et al., 2010).

According to the process model of ER by Gross and John (2003), the timing of regulation is critical: expressive suppression (inhibition) is a typical late response-focused strategy and less effective and more detrimental to mental health as compared to antecedent-focused regulation, such as cognitive reappraisal. We lack knowledge about the ways how children prenatally exposed to maternal SUD use these developmentally salient ER strategies to manage emotions of sadness and anger in middle childhood, which is the contribution of the current study.

1.2. Maternal substance use, early interaction and child emotion regulation

Infants have limited means of regulating their emotions, such as shifting attention from threatening stimuli towards safety-eliciting ones (Calkins, 1994; Sheese et al., 2008), and therefore rely on their caregivers for attuning distress and granting security (Loman and Gunnar, 2010). According to *the mutual regulation model* by Tronick and Beeghly (2011), the foundation of self-regulation is shaped through repeated interactions with a caregiver who responds promptly and sensitively to the infant's distress. With the aid of an emotionally available caregiver, children gradually move from their initial complete dependency on maternal co-regulation into increasing capacity of self-regulation of emotional states (Calkins, 1994; Beeghly et al., 2011). Thus, high-quality dyadic interaction is considered fundamental in shaping optimal development of ER.

Maternal substance use exerts harmful effects on child development via compromised parenting, in addition to the teratogenic exposure and socio-economic adversities (Conners et al., 2004; Salo and Flykt, 2013). Mothers with SUD face difficulties in fulfilling their infants' physical and emotional needs (Hatzis et al., 2017; Parolin and Simonelli, 2016), and they show low emotional availability (EA), involving low sensitivity, poor structuring and high intrusiveness and hostility (Belt et al., 2012; Frigerio et al., 2019; Salo et al., 2009). Infants of mothers with SUD in their part tend to show low responsiveness and involvement (Belt et al., 2012; Salo et al., 2009), and high negative engagement and low synchrony (Tronick, 2005) in the dyadic interaction.

The mechanisms that explain why maternal SUD compromises dyadic interaction quality may relate to mothers' deficient skills in regulating their own attention, emotions, and mood (Eiden et al., 2018; Håkansson et al., 2015). They may also be overwhelmed by feelings of guilt about their substance use risking the child health, feel incompetent in soothing distressed infants, and fear their neediness (Pajulo et al., 2012; Suchman et al., 2010). Importantly, maternal SUD may also physically lead to difficulties in reading the emotional facial and vocal cues of their infants, which is confirmed in brain research. Infants' affective faces, expressing happy, neutral, and sad feelings, elicited more blunted responses in substance using mothers' prefrontal, visual processing and limbic brain regions, as compared to non-using mothers (Kim et al., 2017). Further, infants' high vs. low distress stimuli (crying) elicited similar neural pattern in substance using mothers, who demonstrated reduced neural activation in prefrontal auditory sensory processing and limbic regions, opposite to non-using mothers showing high brain activation to high infant crying (Landi et al., 2011). There is evidence that substance using mothers show blunted neural responses especially to infants' positive cues in brain areas associated with reward, which may indicate that the reward circuits of mothers with SUD are co-opted with addiction instead of pleasure from the dyadic interaction with the infant (Rutherford and Mayes, 2017).

Research is inconsistent on the relative contribution of maternal substance use and parenting quality on children's ER. Lowe et al. (2017) found that high maternal unresponsiveness rather than prenatal alcohol and substance abuse, predicted infant negative affect (high yelling,

crying, fussing and low smiling). Differently, however, Eiden et al. (2009) showed that prenatal exposure to maternal cocaine use was associated with narrow and inflexible ER rather than the insensitive, negative, and non-involved mothering.

There is evidence that heightened neurobiological vulnerability to ineffective ER might make substance exposed children more susceptible to negative caregiving effects (Moe and Slinning, 2002), thus suggesting a mediating role of poor mother-infant interaction quality between exposure and children's ER problems. Eiden et al. (2018) identified two independent paths from prenatal cocaine exposure to toddlers' dysfunctional ER (high demandingness and negative affect, and low self-reliance and responsiveness): through insensitive caregiving practices and mother's own ineffective ER and through infant's high physiological ER (respiratory sinus arrythmia, RSA).

Concerning middle childhood, Crossley and Buckner (2012) found that both current maternal use of alcohol and illicit drugs and her parenting practices had independent effects on children's self-regulation capacity, i.e., children whose mothers were frequent users and those who experienced inconsistent, harsh and negative parenting showed deficient EF and ineffective ER. The current study focuses on the role of early mother-infant interaction in mediating the impact of SUD on children' developmentally salient ER strategies.

1.3. The aims of the study

The aim of this study is to examine, first, how prenatal maternal substance use disorder (SUD) is associated with children's emotion regulation (ER) strategies in middle childhood. We hypothesize that children with maternal history of prenatal SUD show lower level of adaptive emotion regulation (such as cognitive reappraisal) and higher levels of emotion dysregulation (such as agitation and acting out) and emotion inhibition (such as suppressing aroused emotion and hiding them from others) than comparison children of mothers without history of substance use. We further examined the association between severity of the substance use (polysubstance use and intravenous use) and children's ER within the SUD group.

The second aim is to examine, how mother-infant interaction quality in the first year contributes to children's ER strategies in middle childhood. We hypothesize that low maternal EA (low sensitivity and structuring, and high hostility and intrusiveness) and low infant EA (low responsiveness and involvement) would be associated with lower adaptive emotion regulation and higher emotion dysregulation and emotion inhibition in both the SUD and comparison groups.

The third aim is to examine whether the effect of prenatal maternal SUD on children's ER strategies is mediated via maternal and infant EA. We hypothesize that SUD is associated with low maternal and infant EA, which in turn predicts children's lower adaptive emotion regulation and higher emotion dysregulation and emotion inhibition.

2. Method

2.1. Participants and procedure

The study group consisted of mothers with diagnosed SUD (n = 52), all with a history of severe illegal drug or polysubstance misuse that had lasted for several years. The SUD mothers were recruited during the third trimester of pregnancy (Mean gestational week: 34.61, SD 4.70) from two outpatient clinics in Southern Finland offering integrated parenting and SUD treatments. The comparison group consisted of non-using mothers (n = 50) recruited during the third trimester of pregnancy from hospital outpatient clinic where they had contact due to pregnancy complications, such as gestational diabetes or preterm contractions. The exclusion criteria for comparisons were no previous illegal drug-use or alcohol misuse or current psychosocial treatment for mental health problems.

Figure 1 flow-chart illustrates that SUD and comparison mothers and their children participated in pregnancy (T1), when infants were four (T2) and 12 months (T3) months, and in middle childhood (8–12 years, T4). The participation rates varied from 92% at T2 to 38% at T4 in the SUD group and from 86% to 62% respectively in the comparison group. At T2 and T3, the drop-out rates did not differ for SUD and comparison groups, and were not related to mother's employment situation or economic problems. Instead, the drop-outs were higher among dyads with lower maternal education, χ^2 (2) = 14.66, p < .01, and single marital status, χ^2 (1) = 16.04, p < .01.

The participation rates between SUD and comparisons differed significantly at T4, SUD dyads having higher drop-out than comparisons, χ^2 (1) = 5.65, p = .02. The T4 drop-out was not dependent on marital
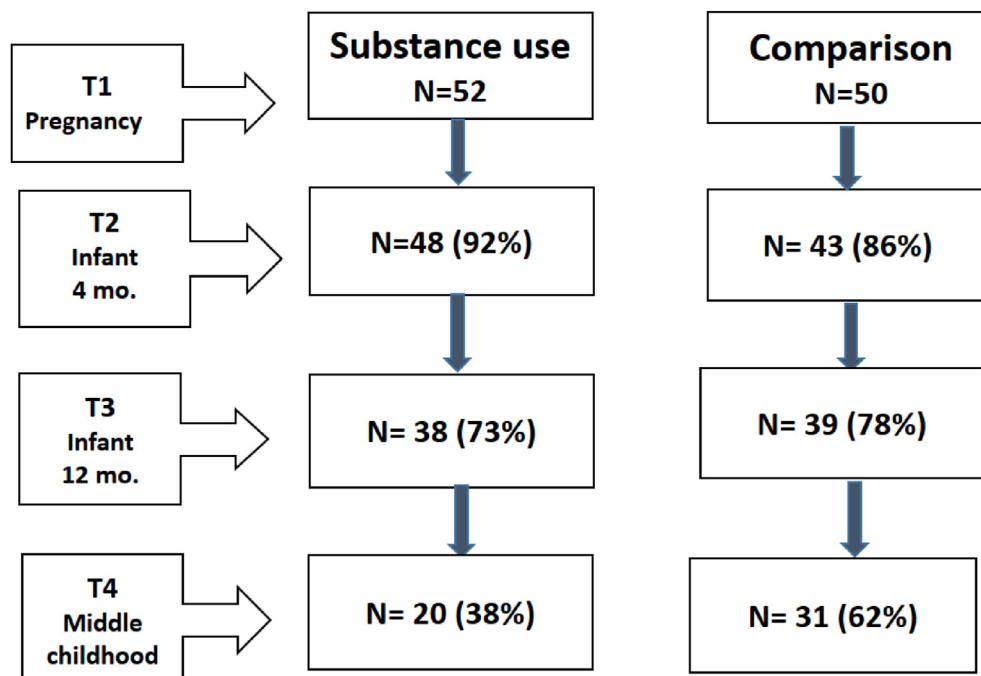

Figure 1. Flow-chart of the prospective developmental study of substance using and comparison mothers and their children.

status, $\chi^2(1) = 0.99$, $p = .32$, maternal education, $\chi^2(2) = 5.59$, $p = .06$, economic problems, $\chi^2(1) = 3.24$, $p = .07$, mother's substance use at T2, Fisher exact test $p = 1.0$ or at T3, Fisher's exact test $p = .45$, maternal EA at T2, $t(81) = -1.35$, $p = .18$ or at T3, $t(76) = -1.55$, $p = .13$, or infant EA at T2, $t(81) = -1.79$, $p = .08$ or at T3, $t(76) = -1.51$, $p = .14$.

The participants were informed about the study and signed an informed consent form at T1 The T2 and T3 assessments were conducted at women's homes or in the outpatient clinics. At T4 the mothers were first contacted by an information letter, including an informed consent form. To indicate their interest to participate, they were asked to either return the consent form via mail (to allow further contact by phone) or contact researchers by phone to obtain more information about the study. Eight mothers in the SUD group could not be reached: three had died, and five had no permanent address. The rest refused or did not response to the letter. In eight cases (three SUD and five comparisons), the mother participated without the child. Two comparison mothers had twins, and data from one (randomly selected) twin was used in the analyses. Six of the SUD group children were in foster care, and with permission from the biological mother, the foster mothers were also contacted. Three foster mothers participated together with the biological mothers, and in one case, only the foster mother participated.

The study was approved by the Ethical committees of Päijät-Häme Central Hospital and the City of Tampere at T1-T3 and by the Pirkanmaa Hospital District at T4. The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions.

2.2. Measures

Background variables. Background factors at T1 were reported by mothers on a questionnaire, including parity, mother's marital status, education, and economic difficulties. At T2, mothers further reported about child sex. Child age at T4 was calculated from the birth date.

Substance use. The referring medical units had made the SUD diagnosis. Women in the SUD group also reported at T1, T2 and T3 by a questionnaire whether they had used illegal drugs (1 = no 2 = yes: cannabis, LSD, amphetamine, ecstasy, heroin, cocaine, sniffing substances, medicine misuse and other, e.g. buprenorphine). We also calculated the total number of substances they had used. Further, they indicated by an open question how often they had used each drug. At T1 women reported their substance use before pregnancy, and whether it had changed during the pregnancy (1 = no change, 2 = decreased, 3 = stopped, and 4 = increased; further categorized as abstinence (score 3) or non-abstinence (scores 1, 2, and 4). At T2 women reported the substance use after the child was born, and whether there had been changes in the use after the child was born (from birth to 4 months). They were further inquired whether they had intravenous drug use (1 = no, 2 = yes), substitute medication (1 = no, 2 = yes), and perceived harm from illegal substance use (1 = no, 2 = yes) at T1 and T2.

Mother-infant interaction. The mother-infant interaction quality was measured at T2 and T3 with Emotional Availability (EA) scales, 4th edition (Biringen, 2008). The mother was asked to play with the infant as usual, and the 10–15 min free-play interaction was videotaped. Maternal EA scales comprise *maternal sensitivity*, i.e., maternal positive emotional expression and adaptive reactions toward the child, *maternal structuring*, i.e., guiding and scaffolding the child in a developmentally appropriate way, *maternal non-intrusiveness*, i.e., ability to refrain from negatively interfering, overstimulating or over-protecting the child, and *maternal non-hostility*, i.e. maternal ability to regulate her negative affect expression. Infant EA scales comprise *child responsiveness*, referring to the child's ability to respond to the mother both behaviorally and emotionally, and *child involvement,* implying the child's own initiative toward the mother. All scales were coded on a 7-point scale (1–7) by two reliable coders blind to maternal group status and background information. Inter-rater reliabilities ranged between .82 and .97 at T2 and between .85 and .97 at T3. Average composite scales were constructed from mothers' and

infants' dimensions at both time points to indicate early maternal and infant EA. Total EA scales are commonly used in research, high scores indicating optimal dyadic interaction quality (Biringen and Easterbrooks, 2012).

Emotion regulation. Children's ER was assessed by Children's Emotion Management Scales (CEMS) and its parent version (P-CEMS) by Zeman and colleagues (Zeman et al., 2001; Zeman et al., 2002). The CEMS and P-CEMS assess children's sadness (11 items) and anger (12 items) management with three subscales: *adaptive emotion regulation* (e.g., "When I am feeling sad, I do something totally different until I calm down"), *emotion dysregulation* (e.g., "I say mean things to others when I am mad"), and *emotion inhibition* (e.g., "I get sad inside but I don't show it"). Children themselves and the mother and/or foster mother estimated how often the child manages anger and sadness in the described ways by using a three-point Likert scale (1 = hardly ever, 2 = sometimes, 3 = often). Composite scales were first constructed for sadness and anger, related to adaptive emotion regulation, emotion dysregulation, and emotion inhibition, separately for children, mothers, and foster mothers. To economize information, these multi-reported scales were next averaged to represent the three ER subscales with combined sadness and anger. The reliabilities were for adaptive emotion regulation $\alpha = .72$ and for emotion dysregulation $\alpha = .90$. However, including foster mother's evaluations in the emotion inhibition scale resulted in a very low reliability, so emotion inhibition scale of combined sadness and anger scales was constructed by using averaged values reported by children themselves and their mothers, having reliability of $\alpha = .72$.

Auxiliary variables. To imputate the missing variables at T4 the following auxiliary variables were at T1: *Maternal pregnancy-related stress* was assessed by 10-item Pregnancy Anxiety Scale (PAS, Levin, 1991); *Social* support by Social 12-item Multidimensional Perceived Social Support Scale-Revised (MPSSS, Zimet et al., 1988); *Depressive symptoms* by a 23-item questionnaire combining ten-item Edinburgh Postnatal Depression Scale (EPDS: Cox et al., 1987) and 13 items from the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977)*; and Aggressive symptoms by* Symptom Checklist (SCL-90R; Derogatis and Cleary, 1977). *At T2 and T3 Maternal anxiety* was assessed by Beck Anxiety Inventory (BAI; Beck et al., 1988), and at T2 Baley-II Motor Development Index.

2.3. Statistical analyses

Descriptive analyses were conducted with SPSS, version 25. Chi-square tests were used to analyze the associations between SUD and comparison group status and background variables including child sex, mother's education level (high/low), presence of economic problems (yes/no), being a single parent (yes/no) and parity (primi/multiparous). Student's t-tests were used to analyze the group differences in continuous variables of age, maternal and infant EA, and children's ER.

To answer our research questions, Mplus version 8 (Muthén & Muthén, 1998–2017) was used. Missing values were handled with Full Information Maximum Likelihood (FIML), which is more reliable than listwise deletion when the level of missingness is high (Graham 2003). It is recommend that in case of missingness >50%, FIML with auxiliary variables (i.e., variables that correlate with at least .40 with the study variables) should be used to reliably estimate the missing data (Collins et al., 2001; Graham, 2003). Eight variables from T1-T3 that both correlated highly with the study variables and were theoretically meaningful were used as auxiliary variables. Furthermore, mother and infant EA scores at T2 and T3 were used for the first study question that did not include EA as a predictor. The MLR (maximum likelihood robust) was selected to compute point estimates as it is robust against non-normality of the observed variables.

To answer the first research question about differences between SUD and comparison groups in children's ER, we built regression models with SUD group status as a predictor and children's adaptive emotion regulation, emotion dysregulation, and emotion inhibition as dependent

variables. To examine the role of substance use severity (polysubstance use, as indicated by number of substances used, and intravenous use) we used a regression model within the SUD group only, where number of substances and intravenous use were predictors and children's ER variables were dependent variables. To answer the second question about the first year maternal EA and infant EA associating with children's ER in SUD and comparison groups, we separately analyzed the effect of maternal and infant EA on children's adaptive emotion regulation, emotion dysregulation and emotion inhibition. We conducted the analyses both with and without maternal SUD group status in the model, but as the results remained the same, we only reported the analysis with both SUD and EA in the same model. Third, we used the delta method in Mplus for mediation analyses to examine whether maternal and infant EA mediated the effect of SUD on children's ER. Background variables that were correlated with both SUD and EA were used as covariates in all models. Further, children's age at T4 was covaried as it varied between 8-12 years.

3. Results

3.1. Descriptive statistics

Table 1 shows the differences in background variables between the SUD and comparison groups. The SUD mothers had lower education, more economic problems, and were more often single parents than the comparisons. There was no group difference in parity or child gender.

Table 2 presents associations between background variables and study variables of EA and ER. Lower maternal education was associated with lower maternal and infant EA, and economic problems with lower infant EA during the first year. As maternal education level and economic problems were associated both with SUD and EA, they were used as covariates in all main analyses, in addition to child age at T4.

3.2. Maternal SUD, dyadic EA and children's ER

Our first research question was whether children in the SUD and comparison groups differed in their ER at school-age. As hypothesized, the results in Table 3 indicate that SUD group children showed significantly lower level of adaptive emotion regulation than comparison children. Contrary to the hypothesis, the SUD group children did not show more emotion dysregulation or emotion inhibition than

comparison children. Covariates of child age, economic difficulties, and maternal education level were not significant. Concerning the severity of substance use within the SUD group, our results indicated that higher number of substances used was associated with higher children's emotion inhibition, $\beta = .49$, 95% C.I. [.15, .83], S.E. = .18, $p = .005$. Intravenous use was not associated with children's ER.

Our second question was how maternal and infant EA during the child's first year were associated with children's ER in maternal SUD and comparison groups in middl childhood. As hypothesized, the results in Tables 4 and 5 show that lower maternal EA was significantly associated with children's higher emotion dysregulation. Contrary to the hypothesis, lower maternal EA was not associated significantly with low adaptive emotion regulation or high emotion inhibition, and infant EA was not significantly associated with children's ER. The SUD group status remained significant for lower adaptive emotion regulation in both models including and excluding maternal or infant EA. None of the covariates were significant.

Our third question was whether maternal or infant EA mediates the effect of maternal SUD on children's ER. The results supported our hypothesis in revealing that the effect of maternal prenatal SUD on children's emotion dysregulation was mediated via maternal EA (Figure 2), total indirect effect being $\beta = .18$, 95% CI [.09, 2.80], $SE = .09$, $p = .04$. No mediation effects were found on adaptive emotion regulation or emotion inhibition. Contrary to our hypothesis, infant EA did not mediate the effect of maternal SUD on children's ER, as total indirect effect was $\beta = .08$, 95% CI [-.02, .19], $SE = .05$, $p = .12$.

4. Discussion

The prospective study examined how maternal prenatal SUD with polysubstance use and the quality of mother-infant interaction during the first year predict children's emotion regulation (ER) in middle childhood. The findings indicate that maternal SUD deprived children from using adaptive or effective ER, whereas non-optimal mother-infant interaction, specifically low maternal emotional availability (EA) was associated with child emotion dysregulation. Within the SUD group, more severe substance use, indicated by a high number of substances, predicted high emotion inhibition. Findings also suggest that low early maternal EA can function as underlying mechanism for the effect of SUD on children's later emotion dysregulation. Thus, enhancing optimal parenting can be

Table 1. Associations between substance use group status and background variables.

	SUD		Comparison		χ^2 (1)	p
	n	%	n	%		
Child sex					0.84	.36
Girl	17	37%	20	46.5%		
Boy	29	63%	23	53.5%		
Mother's marital status					18.31	**<.001**
Married or cohabiting	28	57.1%	47	94%		
Single	21	42.9%	3	6%		
Mother's education level					27.43	**<.001**
Lower	47	94%	23	46%		
Higher	3	6%	27	54%		
Economic problems					21.17	**<.001**
Yes	37	74%	14	28%		
No	13	26%	36	72%		
Parity					0.008	.93
Primiparous	23	45.1%	23	46%		
Multiparous	28	54.9%	27	54%		

Note. SUD = Substance use disorder. Background variables were measured at T1 (pregnancy) except for child sex which was measured at T2. The significant p-values for differences are in bold.

Table 2. Associations between background and study variables.

	Maternal EA				Child EA				ER: Dysregulation				ER: Adaptive emotion regulation				ER: Inhibition			
	M	Sd	t (df)	p	M	Sd	t (df)	p	M	Sd	t (df)	p	M	Sd	t (df)	p	M	Sd	t (df)	p
Child sex			0.93 (86)	.35			1.00 (86)	.32			-0.42 (47)	.68			0.04 (47)	.97			-0.64 (47)	.52
Girl	4.66	0.83			4.15	0.95			1.84	0.30			1.98	0.32			1.55	0.28		
Boy	4.47	1.04			3.92	1.11			1.88	0.35			1.98	0.37			1.60	0.27		
Marital status			1.16 (87)	.25			1.12 (87)	.27			-0.80 (48)	.43			0.58 (48)	.57			0.19 (48)	.85
Married/cohabiting	4.62	0.93			4.11	1.08			1.87	0.32			2.00	0.33			1.59	0.29		
Single	4.35	1.06			3.81	1.00			1.97	0.41			1.93	0.36			1.58	0.17		
Education level			-3.03 (88)	**.003**			-2.69 (88)	**.009**			0.95 (48)	.35			-1.49 (48)	.14			-0.13 (48)	.90
Lower	4.35	0.98			3.83	1.07			1.93	0.33			1.93	0.33			1.59	0.21		
Higher	4.98	0.80			4.45	0.91			1.83	0.35			2.07	0.33			1.60	0.35		
Economic problems			-1.92 (87)	.058			-2.31 (87)	**.023**			0.59 (48)	.56			-0.13 (48)	.90			0.63 (48)	.53
Yes	4.36	0.98			3.78	1.10			1.92	0.33			1.98	0.28			1.62	0.26		
No	4.75	0.92			4.29	0.97			1.87	0.35			1.99	0.38			1.57	0.28		
Parity			-1.40 (89)	.17			-1.30 (89)	.20			1.44 (49)	.16			0.40 (49)	.69			-0.98 (49)	.33
Primiparous	4.42	.97			3.89	1.20			1.95	0.34			1.99	0.31			1.54	0.19		
Multiparous	4.70	.96			4.17	0.90			1.81	0.34			1.96	0.36			1.62	0.33		

Note: EA = Emotional availability. The significant p-values for differences are in bold.

Table 3. Mother's substance use and child emotion regulation.

	Dysregulation				Adaptive regulation				Inhibition			
	β	SE	95% CI	p	β	SE	95% CI	p	β	SE	95% CI	p
SUD group status	.16	0.17	[-.18, .49]	.35	-.47	0.12	[-.71, -.23]	<.001	.07	0.18	[-.28, .42]	.69
Child age	-.21	0.20	[-.61, .18]	.29	-.06	0.16	[-.38, .25]	.70	-.10	0.20	[-.48, .29]	.63
Education level	.02	0.12	[-.21, .24]	.88	.02	0.11	[-.30, .25]	.86	.09	0.15	[-.20, .38]	.56
Economic problems	.15	0.11	[-.07, .36]	.19	-.11	0.14	[-.39, .16]	.42	.04	0.14	[-.24, .32]	.77
Effect size	$R^2 = .08$				$R^2 = .19*$				$R^2 = .02$			

Note. *p < .05.

Table 4. Mother's substance use, maternal EA and child emotion regulation.

	Dysregulation				Adaptive regulation				Inhibition			
	β	SE	95% CI	p	β	SE	95% CI	p	β	SE	95% CI	p
SUD group status	.05	.18	[-.31, .41]	.80	-.49	.20	[-.89, -.10]	.02	.01	.24	[-.46, .49]	.95
Mother's EA	-.33	.15	[-.62, -.05]	.02	.11	.19	[-.25, .47]	.55	-.01	.13	[-.27, .24]	.92
Child age	-.20	.18	[-.55, .15]	.27	.02	.18	[-.33, .37]	.91	-.05	.21	[-.45, .35]	.80
Educational level	.08	.13	[-.17, .32]	.54	-.01	.14	[-.28, .26]	.95	.12	.17	[-.22, .46]	.49
Economic problems	.03	.16	[-.29, .35]	.85	-.23	.14	[-.52, .04]	.10	-.06	.15	[-.36, .25]	.72
Effect size	$R^2 = .16$				$R^2 = .25*$				$R^2 = .01$			

Note. EA = Emotional availability.
*p < .05.

Table 5. Mother's substance use, child EA and child emotion regulation.

	Dysregulation				Adaptive regulation				Inhibition			
	β	SE	95% CI	p	β	SE	95% CI	p	β	SE	95% CI	p
SUD group status	.13	.22	[-.30, .55]	.57	-.55	.17	[-.89, -.21]	.002	-.03	.25	[-.52, .46]	.92
Child EA	-.22	.14	[-.49, .05]	.11	.02	.15	[-.27, .30]	.91	-.05	.15	[-.35, .25]	.73
Child age	-.16	.20	[-.54, .22]	.42	.008	.14	[-.26, .28]	.95	-.05	.18	[-.41, .31]	.79
Educational level	.08	.13	[-.17, .34]	.53	-.01	.13	[-.28, .25]	.91	.11	.17	[-.23, .45]	.53
Economic problems	.05	.14	[-.21, .32]	.71	-.25	.13	[-.51, .001]	.051	-.08	.15	[-.37, .22]	.61
Effect size	$R^2 = .11$				$R^2 = .24*$				$R^2 = .02$			

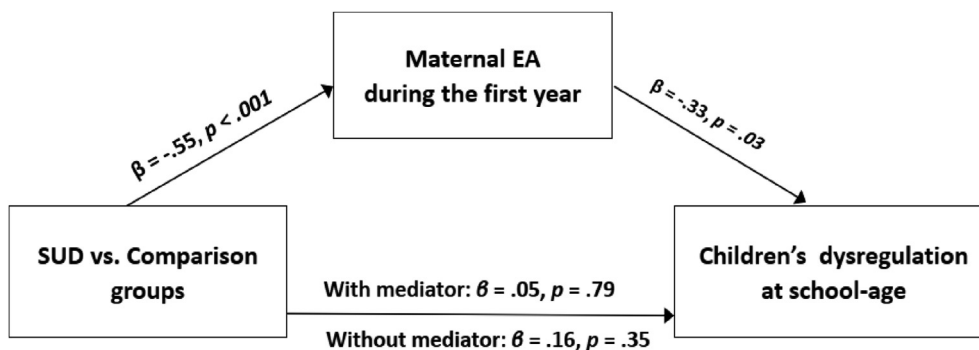*Note*. EA = Emotional availability.
*p < .05.

Figure 2. The early maternal emotional availability mediating between prenatal exposure to maternal drug abuse and children's emotion dysfunction. *Note.* The total indirect effect was significant, ($\beta = .18$, 95% CI [.09, 2.80], $SE = .09$, $p = .04$).

pivotal when tailoring effective interventions for dyads with substance use problems.

4.1. SUD harms adaptive emotion regulation

Our result of maternal SUD interfering with children's adaptive ER, but not increasing their emotion dysregulation differs from findings among prenatally substance exposed infants and toddlers. They typically show negative emotionality, low soothability, and high physical reactivity (Eiden et al., 2009; LaGasse et al., 2012). The result may relate to the developmental salience of more intrinsic effective coping and repertoires of ER strategies required in middle childhood, as compared to extrinsic caregiver-aided managing of threats, arousals and distress in infancy and toddlerhood (Rothbart et al., 2003). It is also possible that prenatal substance exposure 'preprograms' the infant's ER into dysregulation that reflects more basic bottom-up responses (Gautam et al., 2015), whereas the negative impact of SUD on later ER development reflects the age-specific vulnerability of more top-down adaptive regulatory systems, enabled by effective working of EF and other sophisticated adaptive cognitive processes (Thompson and Goodman, 2010; Salisch, 2001). Research has confirmed that prenatal exposure to substances can negatively impact the development of EF, especially by increasing impulsiveness (Ackerman et al., 2010; Lester and LaGasse, 2010).

In adaptive emotion regulation, children apply strategies that adequately help them modulate the duration, content or intensity of their emotional expression in a flexible and socially appropriate manner (Gross and Jazaieri, 2014; Zeman et al., 2001). Children exposed prenatally to maternal SUD face difficulties in coping constructively with aroused feelings of anger or sadness, as they were endorsing infrequent effective strategies, such as distracting attention to other more positive issues or reappraising situation before directing anger to others. Low use of adaptive emotion regulation can further interfere with children's gaining of important goals, such as maintaining rewarding peer relations and achieving good school grades (Brumariu and Kerns, 2013; Eisenberg et al., 2010; Eisenberg et al., 2000).

Substance exposed children often live in unstable and unpredictable home environments (Conners et al., 2004), and subsequently they can have a highly responsive and easily activated threat system that generates intense negative emotions and can overwhelm realistic evaluation of aroused emotions (Abar et al., 2013; Goldstein et al., 2009). These observations may explain why children prenatally exposed to maternal SUD faced difficulties in accessing adaptive emotion regulation and effective coping responses when feeling angry or sad.

4.2. Polysubstance use predict high emotion inhibition

Importantly, mother's usage of multiple substances rather than her SUD alone was predictive of children's high emotion inhibition of suppressing or hiding feelings of anger and sadness. Inhibiting expression of

emotional arousal is considered functional in some highly threatening environments, such as parental maltreatment, but only for a limited time (Shipman and Zeman, 2001). It is possible that maternal polysubstance use in the SUD group bring about chaotic, traumatizing and unpredictable environment where children learn to cope with their high negative arousals by means of inhibition. This accords with observations that prenatally substance exposed children learn to over-regulate their emotions in order to stabilize unpredictable social environment (Chaplin et al., 2010; Smith et al., 2015) or that children of SUD mothers have to develop features of false-self in order to protect themselves from unpredictable and oscillating maternal responses (Crittenden and DiLalla, 1988; Savonlahti et al., 2005). These observations were valid in our sample only when the maternal substance use was severe.

It is noteworthy, that prenatal maternal SUD did not generally predict a higher level of emotion inhibition, which was against to our hypothesis. The reason for the lack of differences between the SUD and comparison groups may reflect dynamics that the prenatally exposed children use both hyper-aroused 'fight' mode to prepare for dangers and hypo-aroused 'flight' mode to escape dangers. They may oscillate between inhibitory or under-regulation and excitatory over-regulation, and fail to develop a functional balance between them (van Dijke et al., 2010). Combination of inhibitory and excitatory experiencing states commonly occur in severe dissociation and borderline personality disorders (van Dijke et al., 2010), both which are commonly comorbid in SUD (Vujanovic et al., 2018).

4.3. Early interaction problems increase emotion dysfunction

Poor quality of mother-infant -interaction, comprising of maternal insensitivity, hostility, intrusiveness and lack of structuring, increased the risk of children's later emotion dysregulation. Typically, this kind of ER involves inflexible, behavioral and socially unfit responses, as children, for instance, are slamming doors or saying vicious things to peers when angry or getting nervous and agitated when sad. The early dyadic interaction works as a primary scene for the child to learn ways to regulate distress and painful emotions, originally with the help of the caregiver. A core maternal function is to frame, structure and modulate excessive and threatening emotional arousal (Beeghly et al., 2011). Our results thus substantiated a direct impact of early mother's emotional unavailability on emotion dysregulation in middle childhood, which extended beyond the impact of maternal prenatal SUD.

Importantly, low maternal EA explained the effect of maternal prenatal SUD on children's emotion dysregulation, shown in significant mediation effect. In other words, if SUD leads mothers to employ insensitive, hostile, and intrusive caregiving practices during the first year, the children are at increased risk for emotion dysregulation in middle childhood. The result concurs with research emphasizing parenting as a central mediator between prenatal exposure to substances and child development and mental health (Eiden et al., 2014; Eiden et al., 2018). If SUD mothers show deficiencies in structuring the infant's

emotional communication and are mismodelling their attempts to regulate emotional arousals, children are at heightened developmental risk for ER problems.

The mothers' early interactional problems were more decisive to children's later ER than children's own unresponsiveness and noninvolvement as infants. The result hints that although substance exposed infants may have innate regulatory problems that can lead to dyadic interaction problems from their part in early age (Moe and Slinning, 2002), maternal interactive behavior is still more crucial for later ER. It is thus informative to conceptualize and assess dyadic interaction separately from both the mother's and infant's sides, and always include assessment of maternal interactive capacity in developmental assessments of infants of SUD mothers.

Yet, in future studies it would be important to analyze the role of child characteristics more comprehensively, as, for instance, infant temperament is found to predict ER in normative samples (Santucci et al., 2008; Stifter et al., 2011). Interestingly, a study by Frick et al. (2018) delineated that maternal and infant characteristics may uniquely predict different ER strategies. Maternal sensitivity, but not infant's temperament, predicted toddler's ability to regulate emotional distress to frustration and disengage attention from negative stimuli. Instead, infant early temperament, but not maternal sensitivity, predicted more cognitive self-regulation, indicated by EF. Our findings contribute to understanding early predictors of children's later ER by emphasizing the importance of the maternal interactional characteristics, including sensitivity.

We could not find studies analyzing the impact of SUD on actual ER responses to developmentally salient emotions of anger and sadness in middle childhood, as the foci mostly have been proxies of ER such as EF, mood disorders, or few-item indices of emotion management (Ackerman et al., 2010; Smith et al., 2015). Our results revealed specific impacting paths on children's ER, as SUD associated directly with low adaptive emotion regulation, but indirectly, mediated by EA, with high emotion dysregulation.

4.4. Limitations of the study

The main sources of criticism are our small sample size and a long lag between assessments in infancy and middle childhood. Mothers with SUD face more adversities such as legal encounters, loss of children's custody and unstable living conditions, which partially explained our difficulty to reach a higher number of mothers and their children in middle childhood. Our results should thus be treated as preliminary and should be verified with a larger sample.

Importantly, our research setting would be stronger if we had had assessment points also in toddlerhood and preschool years, and on both the dyadic interaction quality and ER. Also, inclusion of infant temperamental measures could strengthen the setting. The small sample size relates to other deficiencies in our study. For instance, a larger sample would allow to analyse cross-sectional reciprocal relations between mother-child -interaction and children's ER both in infancy and middle childhood. It is plausible that the quality of dyadic interaction is also a consequence and not only a contributor to the development of children's ER strategies (Cole et al., 2004; Kochanska et al., 2009).

Further, researchers remind that the early scene where infants learn ER is more comprehensive than dyadic interaction alone, and it would be intriguing to analyze family relationships involving both parents and siblings predicting ER strategies in SUD and normative families (Lindblom et al., 2016; Little and Carter, 2005). We did not, however, examine father-child relations in this study due to practical reasons, since majority of mothers in the SUD group were single parents and the father was often not involved in the child's life. Also, the accumulation of traumatic and adverse experiences is characteristic to SUD families (Conners et al.,

2004; Carta et al., 2001) and it would be important to include them in analyses in a larger sample.

Finally, the current study used children's self-reports of ER that can grasp only conscious responses to emotionally aroused situations, while ER importantly reflects also automatized processes (Gross and Jazaieri, 2014). Research shows that children with history of maternal SUD show deficiencies in affective mentalization, i.e., awareness and ability to read other people's emotions (Flykt et al., 2021), which may lead to difficulties in evaluating their own inhibitory or other complex and non-behavioral emotion processing. Even though multi-reported method of ER (both mothers and children themselves) was used, it should be noted that also mothers with SUD often have difficulties in their reflective functioning (Katznelson, 2014), which may similarly bias their evaluations of children's ER.

4.5. Clinical implications

The finding that the early mother-infant interaction quality predicted children's ER and explained the association between SUD and later ER problems, calls for tailoring early-onset preventive programs. The mother-infant interaction quality is modifiable as intervention studies among SUD mothers and their infants indicate (Suchman et al., 2011; Belt et al., 2012). Pregnant and caregiving mothers with SUD are motivated to protect their children, and if helped, can substantially improve their dyadic interaction by increasing sensitivity to infants' needs (Punamäki and Belt, 2013). Also, through learning to recognize, express and modulate their own emotions, mothers will provide loving and accurate guidance to their infants, thus enhancing the development of their adequate and effective ER (Kim et al., 2014). Our longitudinal results on children's ER support the role of enhancing positive parenting experiences and caregiver's reflective functioning of her own and the infant's mind as treatment elements for dyads with maternal SUD. Interventions should also directly address children's ER problems and enhance their functional and effective ER in different developmental stages. Some research shows that parenting interventions that involve stabilizing elements of trauma-related mood oscillation can be helpful also for older children in improving children's ER (Afshari et al., 2014).

5. Conclusion

The current study confirmed the dual risk of teratogenic substance exposure and deficient learning of ER in early dyadic interaction in prenatal maternal SUD predicting children's later problems to adaptively modulate their negative emotional experiences. Substance exposed infants may have innate regulatory problems that can lead to challenges in early interaction, but maternal interactive behavior is still a more crucial predictor of later ER than the infant's own behavior.

Declarations

Author contribution statement

Raija-Leena Punamäki: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Marjo Flykt: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Ritva Belt: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Jallu Lindblom: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

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Data availability statement

The data that has been used is confidential.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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