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Lower maternal emotional availability is related to increased attention toward fearful faces during infancy

Eeva Eskola[a,b,c,*], Eeva-Leena Kataja[a], Jukka Hyönä[b], Hetti Hakanen[a,b], Saara Nolvi[a,b,d], Tuomo Häikiö[b], Juho Pelto[a], Hasse Karlsson[a,e,f], Linnea Karlsson[a,e,f], Riikka Korja[a,b]

[a] University of Turku, Department of Clinical Medicine, Turku Brain and Mind Center, FinnBrain Birth Cohort Study, Turku, Finland
[b] University of Turku, Department of Psychology and Speech-Language Pathology, Turku, Finland
[c] Turku University Hospital, Expert Services, Turku, Finland
[d] University of Turku, Turku Institute for Advanced Studies, Turku, Finland
[e] University of Turku and Turku University Hospital, Department of Psychiatry, Turku, Finland
[f] Centre for Population Health Research, University of Turku and Turku University Hospital, Turku, Finland

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ABSTRACT

It has been suggested that infants' age-typical attention biases for faces and facial expressions have an inherent connection with the parent–infant interaction. However, only a few previous studies have addressed this topic. To investigate the association between maternal caregiving behaviors and an infant's attention for emotional faces, 149 mother–infant dyads were assessed when the infants were 8 months. Caregiving behaviors were observed during free-play interactions and coded using the Emotional Availability Scales. The composite score of four parental dimensions, that are sensitivity, structuring, non-intrusiveness, and non-hostility, was used in the analyses. Attention disengagement from faces was measured using eye tracking and face-distractor paradigm with neutral, happy, and fearful faces and scrambled-face control pictures as stimuli. The main finding was that lower maternal emotional availability was related to an infant's higher attention to fearful faces ($p = .042$), when infant sex and maternal age, education, and concurrent depressive and anxiety symptoms were controlled. This finding indicates that low maternal emotional availability may sensitize infants' emotion processing system for the signals of fear at least during this specific age around 8 months. The significance of the increased attention toward fearful faces during infancy is an important topic for future research.

1. Introduction

Faces and facial expressions are important sources of social and emotional information of the environment from very early on and provide a foundation for social interaction and later social-emotional development (Klin et al., 2015; Morales et al., 2016; Senju & Johnson, 2009). Furthermore, the attentional preference for the emotional information of faces has been found to influence infants' attention patterns during the first year after birth: at 7 months of age (Peltola et al., 2009; Yrttiaho et al., 2014) or even right after birth (Farroni et al., 2007). This kind of affect-biased attention has been defined as an attentional preference for an object based on its

* Corresponding author at: University of Turku, FinnBrain Birth Cohort Study, Kiinamyllynkatu 10, 3rd floor, Turku 20520, Finland.
E-mail address: epesko@utu.fi (E. Eskola).

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affective salience, and it is seen as one of the first forms of self-regulation (Todd et al., 2012). Within the framework of the developmental systems theory, Reynolds and Roth (2018) argue that the development of attention biases is influenced by multiple factors, both internal and external to the individual, and the biases subsequently impact on an individual's attention and learning in social contexts. In addition, the previous models of the development of affect-biased attention have emphasized its reciprocal connections to other aspects of social-emotional development (Morales et al., 2016). This assumption about the reciprocal connections between affect-biased attention and social-emotional functioning is based on previous findings concerning the well-established association between the increased attention to threat and anxiety symptoms (Bar-Haim et al., 2007; Dudeney et al., 2015; Mogg & Bradley, 2018). More specifically, an intervention targeted to the decrease in attentional threat-biases has been shown to decrease anxiety symptoms (Hakamata et al., 2010, Van Bockstaele et al., 2014) and an intervention targeted to the decrease in anxiety symptoms has been shown to decrease threat-related attention biases (Banos et al., 2008; Pishyar et al., 2008). Infants' interaction with their parent is an essential external factor that may have connections with the development of affect-biased attention. However, to our knowledge, this is the first study to directly investigate the association between a child's affect-biased attention in face processing and the quality of parenting behaviors during infancy, more specifically at 8 months of age.

One important construct of parental caregiving behaviors is the parental emotional availability (EA) that has been measured with the Emotional Availability Scales (EAS; Biringen et al., 1998, 2008). The construct of EA has been developed based on the attachment theory (Bowlby, 1969), and it is comprised of a parent's ability to regulate emotional interaction within the dyad and a child's inner states and behavior (Biringen et al., 2014). In several previous studies, the maternal EA has been shown to be related to a child's emotion regulation and emotional understanding during their infancy, toddlerhood and pre-school years (Biringen et al., 2014; Garvin et al., 2012). There is one previous study by Taylor-Colls and Fearon (2015) on the maternal EA and infants' neural responses to emotional faces using EEG measurements in 7-month-old infants. They reported an association between a higher maternal EA (i.e., the composite score of maternal dimensions of EAS) and one key event related EEG component, that is a larger negative central (NC) amplitude, to happy compared to neutral faces but not to fearful faces compared to neutral faces. Their interpretation of these results was that the infants of the mothers with higher EA encode or evaluate emotional expressions differently and may attach greater motivational value to them. However, the task of their study consisted of trials with single face pictures, and thus, the paradigm did not involve the attention orienting processes such as attentional disengagement, shifting and engagement (Yiend, 2010). To further our understanding about the possible association between the maternal EA and infant processing of emotional faces, in the present study, the infant affect-biased attention was explored using the eye tracking and a face-distractor paradigm involving distractors attracting the attentional disengagement from emotional face stimuli.

The development of the attention to faces and the affect-biased attention undergoes rapid chances during infancy and toddlerhood (Peltola et al., 2009; Xie et al., 2019; Yrttiaho et al., 2014). Previous studies in 7, 8, 9, and 12-month-old infants have demonstrated that infants show a specific attention bias for fearful faces over happy and neutral faces (Kataja et al., 2020; Leppänen et al., 2018; Nakagawa & Sukigara, 2012; Peltola et al., 2008; Pyykkö et al., 2018). There are evidence from longitudinal studies that an attention bias for fearful faces emerges between 5 and 7 months of age and starts to decline by 2 years of age (Kataja et al., 2022; Peltola et al., 2009; Peltola et al., 2018; Yrttiaho et al., 2014). These normative changes in the attention biases may support an infant to reach age-typical social-emotional developmental milestones, e.g., the bias for fear emerges at a time or just before the infant begins to independently explore the world and information about the safety of the environment becomes more relevant (Bertenthal & Campos, 1984; Leppänen & Nelson, 2012). In previous studies, a higher attention bias for fearful faces versus happy, and neutral faces at 7–8 months of age has been related to positive outcomes in social development, such as a secure attachment at 14 months of age (Peltola et al., 2015), helping responses at 14 months (Grossmann et al., 2018) and better social-emotional competencies at 2 years (Eskola et al., 2023). Thus, the affect-biased attention, here an attention bias for fear, specifically during the second half of the first year after birth can be viewed as an adaptive mechanism supporting development and possibly also the parent–infant relationship.

Although the association between the quality of the caregiving behavior and a child's affect-biased attention is unexplored, previous studies have investigated at least three other caregiver-related factors and a child's affect-biased attention. First, adverse experiences in the family environment, for example, by living in a hostile family environment or in an orphanage, impact on the individual variance in affect-biased attention and attention biases for threat later during childhood (Loman & Gunnar, 2010; Pollak, 2015; Teicher & Samson, 2016). More specifically, negative parenting styles and behaviors have been related to the attention bias toward angry faces (Gibb et al., 2011; Gulley et al., 2014); moreover, abused children identify accurately angry faces with less information compared to nonabused children (Pollak & Kistler, 2002; Pollak & Sinha, 2002). In addition, more complex findings on the association between the family system type and the early and late-stage attention bias toward and away from angry faces have been reported (Lindblom et al., 2017). Second, maternal pre- and postnatal depressive and anxiety symptoms that are frequently linked with the poorer quality of caregiving and negative engagement with the infant (Crugnola et al., 2016; Lovejoy et al., 2000; Seymour et al., 2015) have been associated with an infant's emotional attention, i.e., a higher attention bias towards fearful or angry faces in children younger than 2 years of age (Fu & Pérez-Edgar, 2019; Kataja et al., 2020, 2019; Morales et al., 2017; Otte et al., 2015) and higher neural responses to happy and fearful faces in infants from 5 to 12 months of age (Bowman et al., 2022). However, the results have been inconsistent, as an association between maternal anxiety symptoms and infant emotional attention biases have not been found in some studies in infants from 5 to 19 months of age (Aktar et al., 2021; Leppänen et al., 2018). Third, maternal personality features, more specifically the positive affectivity, have been related to infants' higher attention to fearful versus happy faces at 7 months of age (de Haan et al., 2004). One important mechanism through which early family environment, maternal depressive and anxiety symptoms and maternal personality features may influence an infant's emotional attention is early caregiving behaviors.

The aim of the present study was to investigate the relation between the quality of the maternal caregiving behavior and an infant's attention bias for faces and especially for fearful faces in a normative sample at the age of 8 months. We observed maternal caregiving behaviors during mother–infant free-play situations, and we coded the maternal emotional availability using EAS (Biringen, et al., 2000). The composite score of four maternal dimensions of EAS, that were sensitivity, structuring, non-intrusiveness and non-hostility, was created and used to measure the levels of the maternal EA in mother–infant interactions.

In this study, an infant's attentional preference for faces and affect-biased attention was studied as the probability to disengage an attention from face stimuli using eye tracking combined with an overlap paradigm with neutral, happy, and fearful faces and a scrambled-face control stimulus (Peltola et al., 2008) at 8 monts of age. By using this paradigm, we were able to measure individual differences in the affect-biased attention as the differences in attentional disengagement from single facial expressions. In addition, we were able to compare individual attention biases, i.e., the age-typical face bias (i.e., the attention disengagement from scrambled-face stimuli vs. neutral and happy faces; Yrttiaho et al., 2014) and the fear bias (i.e., the attention disengagement from happy and neutral faces vs. fearful faces; Yrttiaho et al., 2014) between infants.

Our study questions were: 1) how maternal caregiving behaviors, here the maternal EA, are associated with an infant's attention disengagement from neutral, happy and fearful faces towards distractors, and 2) how the maternal EA is associated with infant-typical attention biases, that is, a general attention bias for faces and specifically for fearful faces. In previous studies, maternal depressive and anxiety symptoms at the infant's age of 6 months have been associated with the maternal EA and the attention for emotional faces (Hakanen et al., 2019; Kataja et al., 2020, 2019); thus, they were controlled for in the analyses. In addition, maternal age at the delivery and education have been related to maternal EA (Biringen et al., 2014; MacMillan et al., 2020), so they were also controlled. We made no assumptions of the direction of the associations, as in previous studies infants' higher attention bias for fearful faces has been related to both positive developmental outcomes in social development (Eskola et al., 2023; Grossmann et al., 2018; Peltola et al., 2018) and negative developmental outcomes related to environmental factors, such as maternal depressive and anxiety symptoms (Fu & Pérez-Edgar, 2019; Kataja et al., 2019, 2020; Morales et al., 2017; Otte et al., 2015). Therefore, the analyses were exploratory in nature.

2. Method

2.1. Participants and study design

The participants ($n = 149$ mother–infant dyads, all European) belong to the FinnBrain Birth Cohort Study ($n = 3808$ families, www.finnbrain.fi), which was established to study the effects of early-life distress on later-in-life health and development outcomes. The recruitment for the main Cohort took place at the first trimester ultrasound visits in the South-Western Hospital District and Åland Islands in Finland between December 2011 and April 2015. A research nurse recruited the pregnant mothers at gestational week 12

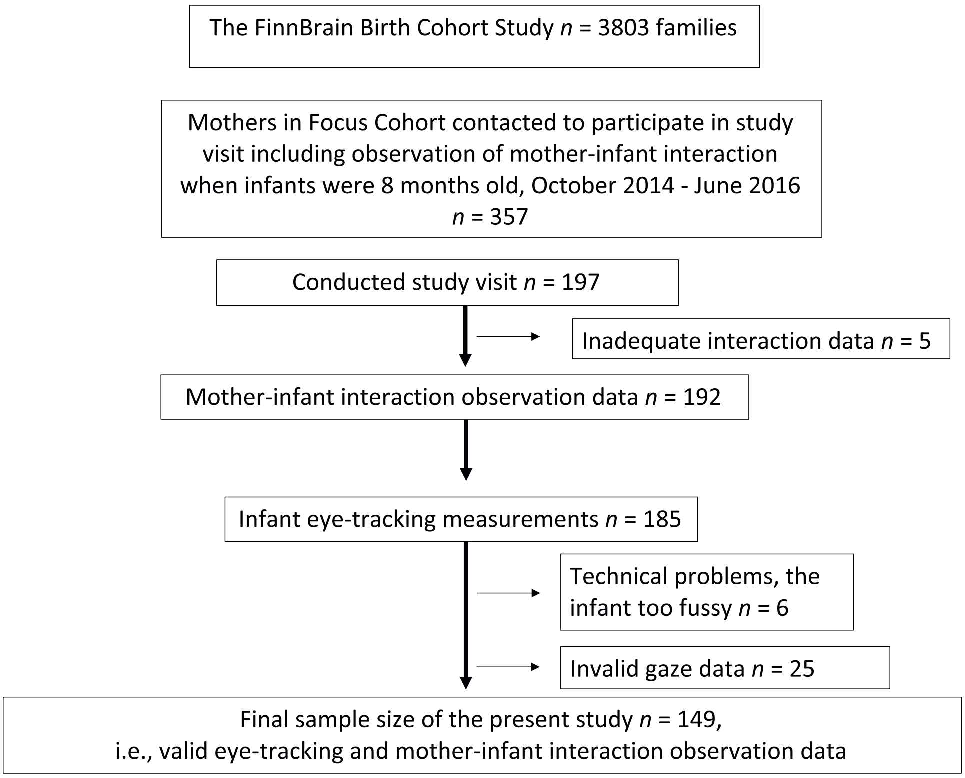

Fig. 1. Flowchart of the recruitment process.

and their spouses. A verified pregnancy and sufficient knowledge of either of the official languages of Finland, Finnish or Swedish, were required. The Cohort study sample represents well the source population of Finland (Karlsson et al., 2018).

The participating 149 mother–infant dyads belong in a sub-study that focuses on the effects of early-life distress on infant development in families at elevated risk. This sample comprised 63 mothers, who reported elevated levels of prenatal depressive, anxiety, and/or pregnancy-related anxiety symptoms and their 69 controls reporting low levels of symptoms. In addition, 17 mothers reported the medium level of symptoms thus not belonging neither to the case nor the control group. The maternal distress symptoms were measured at the gestational weeks 14, 24 and 34 with the Edinburgh Postnatal Depression Scale (EPDS; Cox et al., 1987), the Symptom Checklist-90, Anxiety scale (SCL-90; Holi et al., 1998) and the Pregnancy Related Anxieties Questionnaire-Revised (PRAQ-R; Huizink et al., 2016). At 6 months postpartum, mothers with elevated symptoms during pregnancy reported higher levels of depressive symptoms (EPDS $M = 7.96$, CI [6.61, 9.30] and anxiety symptoms (SCL-90 $M = 7.01$, CI [5.53, 8.50] than the mothers in the control group (EPDS $M = 2.40$, CI [1.46, 3.35]; SCL-90 $M = 0.65$, CI [0.34, 0.96]). Focus Cohort criteria are described in more detail in the Cohort Profile report by Karlsson et al. (2018). The study was conducted in full compliance with the Helsinki Declaration. The study protocols of the FinnBrain Birth Cohort Study were granted approval by the Ethics Committee of the Hospital District of Southwestern Finland. We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study. This study was not preregistered.

The families of the Focus Cohort were invited to take part in the Child Development and Parental Functioning Lab, and the visit of this sub-study took place between March 2013 and June 2016. The visit consisted of the eye tracking of an infant's attention for emotional faces as well as the assessment of an infant's temperament and executive functions, and a free-play situation, where the mother–infant interaction was assessed. The free-play situation was added to the study protocol in October 2014 while other measurements started already in March 2013. Therefore, our data sample is a part of a larger eye-tracking sample (see e.g., Kataja et al., 2020). The visits were led by clinical psychologists or advanced psychology students supervised by a psychologist.

The recruitment process is presented in a flow chart in Fig. 1. A total of 354 mothers were contacted by phone about the study visit at the infant age of 8 months between March 2013 and June 2016. 197 mother–infant free-play situations were conducted after it was added to the study protocols in October 2014. Seven measurements were excluded due to inadequate data ($n = 1$) or the parent being a father instead of a mother ($n = 4$). Of the 192 study visits including the mother–infant free-play situation, 12 visits did not include an eye-tracking measurement because of, for example, a sudden sickness absence of the researcher. Of the initial 180 eye-tracking measurements, 25 (13 %) did not meet the quality criteria described below and 6 (3 %) failed to provide any data as the tracking could not be started or was terminated soon after the start (i.e., the infants were seemingly fussy or did not look at the screen or the calibration of the tracker failed). In all, 149 infants (76 girls) ultimately provided both valid eye-tracking data and observational opportunities for the mother–infant interaction in the free-play situation at the age of 8 months ($mean = 8.13$ months, $SD = 0.22$ months). With this sample size ($n = 149$) we had 43 % power to detect medium effect ($r = .20$; Funder & Ozer, 2019) and 87 % power to detect large effect ($r = .30$; Funder & Ozer, 2019) when the results with the two-sided Bonferroni corrected p values <.05 were

Table 1
The background information of the 192 participants with valid EA data and attrition analysis ($n = 149$ included mother–infant dyads, $n = 43$ excluded mother–infant dyads).

Participant Characteristics	Included Infants ($n = 149$)	Excluded Infants ($n = 43$)	p-value
Infant characteristics	n (%) or median (min.–max.)	n (%) or median (min.–max.)	
Infant sex, girls	73 (49 %)	20 (46.5 %)	.60[3]
Birth order, First-borns	84 (56 %) (missing $n = 3$)	23 (54.8 %) (missing $n = 1$)	.75[3]
Parents live in the same household	136 (100 %) (missing $n = 13$)	42 (97.7 %)	.075[3]
Gestational weeks at birth	39.86 (37.57–42.29)	39.27 (34.43–42.00)	**.030**[4]
Birth weight, g	3595 (2530–4940) (missing $n = 1$)	3450 (2460–4900)	.14[4]
Apgar Score at 5 min	9 (4–10) (missing $n = 1$)	9 (7–10)	.90[4]
Maternal characteristics	n (%) or median (min.–max.)	n (%) or median (min.–max.)	
Age at delivery, years	31 (21–44)	31 (21–39)	.49[4]
SCL-90/ Anxiety	2 (0–21) (missing $n = 25$)	1 (0–28) (missing $n = 8$)	.16[4]
EPDS	4 (0–23) (missing $n = 26$)	3 (0–19) (missing $n = 8$)	.45[4]
Education			
High school, vocational school, or lower	39 (26.2 %)	6 (14.3 %)	.25[3]
Tertiary vocational	54 (36.2 %)	18 (42.9 %)	
University degree, or higher	53 (35.6 %) (missing $n = 3$)	18 (42.9 %) (missing $n = 1$)	
Monthly income	level 4 = 1501–2000e (missing $n = 5$)	level 4 = 1501–2000e (missing $n = 1$)	.35[3]

[1]Maternal Anxiety Symptoms at 6 Months Postpartum (SCL-90), [2]Maternal Depressive Symptoms at 6 Months Postpartum (EPDS), [3] χ^2-test, [4] Mann-Whitney U-test.

considered as statistically significant. We considered this as adequate power for this study where we effectively analyzed simple associations between two continuous variables even though our statistical models were technically more complex.

A total of 84 (56.4 %) infants were firstborns, and all infants were living in the same household with both parents. The distribution of the education of the mothers, divided into three categories, was 26 % (high school, vocational school, or lower), 36 % (tertiary vocational), and 36 % (university degree or higher). In regard to this background information, the only significant difference between the included (n=149) and excluded infants (n=43) was gestational weeks at birth being fewer for the excluded infants (U=2508.00, p=.030).

2.2. Measures

2.2.1. Background factors

Mothers' and infants' background characteristics were obtained from the questionnaires completed by the mothers (gestational week: 14, 24, and 34; postpartum: 3 and 6 months; Table 1). The questionnaires included questions about the mother's education, parity, and whether both parents were living in the same household with the child. Information about an infant's characteristics (i.e., sex, gestational weeks at birth, birth weight, and Apgar Score 5 min after birth) was drawn from the Finnish Medical Birth Register administered by the National Institute for Health and Welfare (www.thl.fi). Maternal depressive symptoms at 14, 24 and 34 gestational weeks during pregnancy and at 6 months postpartum were measured with the Edinburgh Postnatal Depression Scale (EPDS; Cox et al., 1987) and anxiety symptoms with the anxiety subscale of the Symptom Checklist-90 (SCL-90; Holi et al., 1998). In the analyses, the combined sum score of maternal depressive and anxiety symptoms were used.

2.2.2. The mother–infant interaction

The mother–infant interaction was video recorded during a 20-min free-play situation in the laboratory. A researcher offered a standard set of age-appropriate toys and instructed the mother to play with her infant with or without the toys, as they would play at home. The quality of maternal care was coded afterwards using the Emotional Availability Scales (EAS) by two trained coders as recommended (Biringen et al., 1998). Based on previous studies on EAS, at minimum of a 15–20 min interaction is recommended in order to obtain a valid and reliable behavior sample (Biringen et al., 2014).

Emotional Availability. Emotional availability (EA) scales included four adult dimensions used in the present study. These were *Sensitivity*, *Structuring*, *Non-intrusiveness*, and *Non-hostility*. *Sensitivity* includes the mother's behaviors and emotions that create and maintain a healthy and positive connection with the infant. *Structuring* consists of the mother's behaviors that support the infant to learn and sense age-appropriate autonomy. *Non-intrusiveness* refers to the adult's capacity to follow an infant's lead in the play. It refers to the ability to avoid interfering and interrupting the infant physically or verbally. *Non-hostility* refers to the mother's ability to regulate her own negative emotions and to avoid expressing them towards the infant. The coding is based on the maternal behavior during the whole 20-min play situation. A direct score for each dimension is given using a 7-point Likert-type scale describing the evaluator's overall view of the interaction, and these variables were used in the analyses of this study. The higher end of the scale refers to a healthier emotional connection between a mother and an infant. A more detailed description of the scoring is presented in the EA manuscript (Biringen et al., 1998). The coding was made by two blinded, officially trained, and certificated coders. The reliabilities calculated with the interrater correlations were.80 for sensitivity,.72 for structuring,.85 for non-intrusiveness, and.70 for non-hostility. The differences were negotiated between the coders. The medians and the interquartile ranges are reported in Table 2 as well as the correlations between the subscales. Four maternal scales were standardized and summed to form a composite score reflecting the construct of maternal EA in the mother–infant interaction.

2.2.3. Eye tracking of attention for emotional faces

The eye tracking was conducted in a dimly lit room. Infants were seated on their mother's lap at a distance of 50–70 cm from the eye-tracker (Desktop Mount, EyeLink1000 +. SR Research Ltd, Toronto, Ontario, Canada) and 65–85 cm from the screen. The mothers were instructed not to comment on the emotional content of the stimuli on the screen. The researcher conducted the experiment with a host computer behind a curtain and monitored the experiment. Parents were reinstructed in case their behaviors deviated from the given instruction. A five-point calibration and a validation routine were conducted before the tracking. The x- and y-coordinates for the estimated gaze locations were recorded at the frequency of 500 Hz.

An overlap paradigm (Aslin & Salapatek, 1975; Peltola et al., 2008) was used to examine the attention disengagement from a centrally presented facial expression or a scrambled face control stimulus to a lateral distractor (see Kataja et al., 2020). The face

Table 2
Spearman correlations between the subscales of emotional availability.

	Median (interquartile range)	Structuring	Non-intrusiveness	Non-hostility
Sensitivity	5.5 (2.0)	.72*	.50*	.59*
Structuring	5.0 (2.0)		.35*	.41*
Non-intrusiveness	6.0 (2.3)			.50*
Non-hostility	6.0 (2.0)			

* $p = <.01$

stimuli were color images (15.4° x 10.8°) of the facial expressions of two women posing with neutral, happy, and fearful facial expressions on a white background. As the stimulus novelty may influence the infant's looking behavior and especially attentional disengagement (Crockenberg & Leerkes, 2004), only two facial identities were used. The face stimuli were adopted from the study of Peltola et al. (2008). The distractor stimuli were black and white checkerboards or vertically arranged circles (15.4° x 4.3°).

Procedure. Before every trial, an audio-visual animation (e.g., a barking dog) was presented to capture the infant's gaze at the center of the screen. During the 4000-ms trial, the happy, fearful, or neutral face or the scrambled-face stimulus was presented in a semi-random order in the center of the screen so that all the stimuli were presented 6 times but no more than 3 times in a row. After 1000 ms, a peripheral distractor was presented, semi-randomly, to the left or right side of the face at the angle of 13.6° for the remaining 3000 ms. The lateral stimulus was presented at the same side of the screen for no more than 3 times in a row. In a previous study using this same overlap task with unlimited number of trials, 7-month-old infants completed an average of 40 trials before they became too inattentive or fussy to continue (Peltola et al., 2008). Therefore, our measurement consisted of 48 trials (12 trials per condition) with a small break after 24 trials, during which three, 4-second animations were presented on the screen. If the infant was restless, short breaks were also held during the measurement. The eye tracking was terminated if the infant became seemingly inattentive or fussy.

Gaze acquisition and raw data processing. In addition to the xy coordinates of the participants' gaze position, the eye-tracking data included the timestamps for the onset times of the central and lateral stimuli and information about the facial expression and the side of lateral distractor. The data were analyzed offline by using the library of Matlab (Mathworks, Natick, MA) scripts (Leppänen et al., 2015) designed to cope with the challenges of analyzing the data collected from poorly cooperating participants. A trial was viewed as valid if it met three inclusion criteria. First, there was a fixation on the central stimulus over 70 % of the time before gaze disengagement or the end of the analysis period. Second, there were no gaps longer than 200 ms in the gaze data samples. Third, there were no gaps in the gaze data at the time when the gaze disengagement occurred. The infants with valid data from at least 3 trials per condition were included in the final analyses. On average, infants provided a relatively high number of valid trials per condition: scrambled face control stimulus = 9.6 (*SD* = 2.25; *range* = 3–12), neutral = 9.6 (*SD* = 2.28; *range* = 3–12), happy = 9.7 (*SD* = 2.11; *range* = 4–12), and fearful = 10.0 (*SD* = 2.29; *range* = 3–12). The probability of disengagement was calculated for each condition using the whole raw data (Number of trials with disengagement/ Number of all valid trials): scrambled face control stimulus = 0.77 (1118 / 1453), neutral = 0.60 (871 / 1453), happy = 0.60 (872 / 1459) and fearful 0.49 (725 / 1496).

2.3. Eye-tracking variables

Disengagement variable. "Disengagement" was a binary variable indicating whether the infant disengaged his or her attention from the central (i.e., the fearful, happy, or neutral face or the scrambled face) to the lateral stimulus (i.e., a geometric shape) during the analysis period from 1150 ms to 2000 ms after the appearance of the distractor stimulus (i.e., from 150 ms to 1000 ms after the appearance of the distractor stimulus). It was coded as 0 = no disengagement and 1 = disengagement. Invalid trials were treated as missing values. The binary disengagement variable was the only response variable in all the mixed effects logistic regression models described in the next section. The disengagement variable was used in our analyses instead of more conventional variables using the mean saccadic latencies, as the disengagement occurred in less than 50 % of valid trials in the fearful face condition, and, thus, the mean saccadic latencies would have covered less than a half of the trials (Hood et al., 1998).

Estimated Quantities of Affect-Biased Attention. The associations between the EA composite score and the following eye-tracking variables were estimated using the mixed effects logistic regression models. "Disengagement probability" (DP) was defined for the fearful, happy, and neutral face and for the scrambled face as the probability for disengaging the attention from the central stimulus to the lateral distractor. "Fear bias" was defined as the ratio of geometric mean odds of disengaging from the happy and neutral conditions to the odds of disengaging from the fearful condition. That is, a fear bias with an OR > 1 indicates that infants show difficulty in disengaging the attention away from the fearful faces compared to the happy and neutral faces (Kataja et al., 2019, 2020). As previous studies have shown the very specific influence of fearful faces on an infant's attention patterns at 8 months of age (Kataja et al., 2020; Leppänen et al., 2018; Nakagawa & Sukigara, 2012; Peltola et al., 2008), the attention to fearful faces was not included in the definition of the face bias (i.e., only non-fearful faces were used in this measure). "Face bias" was defined in a similar way as the fear bias but it compared the DP of the scrambled face control stimulus to the DPs of the happy and neutral conditions. That is, if infants show difficulty in disengaging an attention away from the happy and neutral face compared to the scrambled face control stimulus, then the face bias is OR > 1 (Kataja et al., 2019, 2020).

2.4. Statistical analyses

The analysis was carried out using a mixed effects logistic regression (MELR) model with the binary disengagement variable (i.e., disengagement or no disengagement) as the response variable. The model had the face as the only infant-specific effect (i.e., random effect). Furthermore, as the DPs depended strongly on the trial number, we controlled for its effect in the model (Kataja et al., 2020). The trial number dependency was modeled by a natural cubic spline with one cut-off point between trials 24 and 25, separately for each face condition (Appendix 1). In addition, maternal age at the delivery, education, and depressive and anxiety symptoms at the infant's age of 6 months were controlled for, because they have been associated with the maternal EA or the attention for emotional faces in previous studies (Hakanen et al., 2019; Kataja et al., 2019, 2020). The model thus had the following fixed effects:

$$\text{Intercept} + \text{Face} + \text{EA} + \text{Control variables} + \text{Face} \times (\text{EA} + \text{Control variables}) + \text{TNS}$$

Here, *Face* is a categorical variable with four levels (neutral, happy, fearful, and scrambled face); *EA* is the EA composite score; and *Control variables* are maternal age, education and infant sex (each analyzed as individual variables) as well as depressive and anxiety symptoms (a combined sum). *TNS* refers to the two trial number spline terms.

To get the result for each face condition, we used each condition as the reference level of the *Face* variable in turn. To analyze the associations between the EA score and the fear or face bias, such contrast codings for *Face* were used in the model that allowed us to compare the average of happy and neutral conditions to the fear condition (fear bias) or to compare the average of happy and neutral conditions to the scrambled face control stimulus (face bias).

The missing values in the control variables (see Table 1) were imputed using missForest (Stekhoven & Bühlmann, 2012).

The Bonferroni method, applied to the set of all 6 *p*-values, was used to adjust the *p*-values for multiple comparisons. The *p*-values smaller than.05 were considered as statistically significant.

All the statistical analyses were performed in R 4.0.2 (R Core Team, 2020)using the lme4 package (Bates et al., 2015) for running the MELR models.

3. Results

3.1. Infant attention for emotional faces

The estimates for median DPs (with 95 % CIs) were highest for the scrambled-face stimulus (.83 [.79;.86]), intermediate for neutral (.64 [.58;.69]) and happy faces (.63 [.58;.68]), and lowest for fearful faces (.49 [.43;.54]). These results demonstrated the age-specific attention bias for fearful faces at 8 months of age previously reported in our study (Kataja et al., 2020) using the complete data set ($n = 363$) and in other studies, for example, by Peltola et al. (2008) and Leppänen et al. (2018) using different data sets.

3.2. Maternal EA and infant attention for emotional faces

First, we analyzed how the composite score of the maternal EA was associated with the DPs for neutral, happy, and fearful faces and for the scrambled face control stimulus (Table 3; see in more detail in Appendix 2). The *p*-values were adjusted for the multiple comparisons using the Bonferroni correction. After controlling for maternal age, education, and current distress (the sum score of anxiety and depressive symptoms at 6 months postpartum) and infant sex, the association between lower the maternal EA and lower DPs for fearful faces was statistically significant (fearful, $OR = 1.11$, 95 % *CI* [1.03, 1.19], $p = .007$, adj $p = .042$; see Table 3). Significant associations between the maternal EA and the DPs for scrambled face control stimulus or neutral and happy faces were not found (all adj $ps > .05$; see Table 3). A full correlation table for all variables is presented in Appendix 3.

3.3. Maternal EA and infant face and fear bias

Second, we analyzed how the maternal EA was associated with the face and fear bias measures. After controlling for the selected covariates, we did not find any significant associations between the maternal EA and the infant's face or fear bias (Table 3).

4. Discussion

We studied the associations between the maternal EA in the caregiving behavior and an infant's attentional disengagement from neutral, happy, and fearful faces at the age of 8 months. Our main finding was that the lower maternal EA was related to the infant's lower probability to disengage attention from the fearful face stimuli, indicating an increased attention towards the fearful expressions. This result remained significant after controlling for infant sex and maternal age, education, and the current symptoms of depression and anxiety and after adjusting the analyses for multiple comparisons. On the other hand, no association was found between the maternal EA and attention to happy or neutral facial expressions or infant-typical attention biases for faces or specifically for fearful faces. In other words, the maternal EA was associated with the disengagement probabilities for a single facial expression of fear and not with the fear bias, defined as the relative difference between the attention for happy and neutral faces versus fearful faces. It is important to note that the number of trials for each face condition was relatively small and the data range was restricted. These

Table 3
The associations between a one-point increase in maternal emotional availability (EA) scales composite score and disengagement probabilities (DPs) for neutral, happy, and fearful faces and the scrambled-face stimulus. The analyses are reported with control variables (maternal age, education and current distress and infant sex). Adjusted *p*-values are calculated using the Bonferroni correction over all 6 *p*-values.

Face Condition	*OR*	95 % *CI*	*p*-value	adj. *p*
Scrambled	1.08	[0.99, 1.17]	.08	.48
Neutral	1.07	[0.99, 1.15]	.09	.54
Happy	1.08	[1.01, 1.16]	.03	.18
Fearful	1.11	[1.02, 1.19]	.007	.042
Face Bias	1.00	[0.95, 1.05]	.95	1
Fear Bias	.98	[.95, 1.02]	.31	1

limitations concern also the bias variables, as they were based on these disengagement probabilities for each face condition.

The association between the lower maternal EA and a higher attention to fearful faces is in line with previous findings on the child's emotional attention and non-optimal contextual factors in family environment. In previous literature, the higher attention bias has been viewed as adaptive or maladaptive depending on the context of the findings. For example, the higher attention bias or heightened neural responses for threat or fear have been related to maternal depressive and anxiety symptoms (Fu & Pérez-Edgar, 2019; Kataja et al., 2019, 2020; Morales et al., 2017; Otte et al., 2015) and the early institutionalized rearing (Parker & Nelson, 2005). Also, abused children overindetified and needed less information to identify angry faces (Pollak & Kistler, 2002; Pollak & Sinha, 2002). It has been discussed that in this context, the hightened sensitivity to angry or fearful faces may be an adaptive trait, as it gives time to prepare reactions to hostile behaviors, but also maladaptive, if it leads to misinterpretations of others' emotions (Pollak & Sinha, 2002). The findings of the present study demonstrated the same direction of the association between the lower maternal EA and the higher attention to fearful faces, although in this sample, the overall levels of maternal EA were high and the variance especially in the non-hostility subscale was low.

One possible explanation for our result is that the EA in the mother–infant relationship may have influenced the development of an infant's emotional attention during the early postnatal period. This is plausible, since the control of attention is one form of self-regulation during infancy (Posner et al., 2014; Rothbart et al., 2011), and caregiving behaviors and especially their emotional aspects have been related to child cognitive and emotional self-regulation in experimental studies (Bridgett et al., 2015; Dix, 1991; Samdan et al., 2020). Further, there are preliminary evidence that the caregiving behaviors are related to the development of a child's neural networks related to self-regulation, as, for example, the early experiences of maltreatment have been related to the volumes of hippocampus and amygdala that are known to be a part of the neural networks that play a role in children's self-regulation (Belsky & de Haan, 2011; Bridgett et al., 2015). According to Callaghan and Tottenham's (2016) model of the neuro-environmental loop of plasticity, the hostility in maternal behavior may lead to hyperactive, threat-related responses manifested as an increased attention towards fearful facial expressions (Callaghan & Tottenham, 2016; Loman & Gunnar, 2010). This developmental explanation is well in line with our findings of the visual attention reflecting those neural and behavioral processes. However, the developmental origin of the connection between the mother–infant interaction and an infant's emotional attention can only be speculated because of the lack of longitudinal data.

There are at least two interpretation frameworks for heightened attention to fear. First, the theories adopting a clinically-oriented framework have considered it as a maladaptive trait, as heightened attention to the signs of fear or threat has been related to anxiety symptoms among children, adolescents and adults (Bar-Haim et al., 2007; Cisler & Koster, 2010; Dudeney et al., 2015; Grossmann, 2022; Mogg & Bradley, 2018). Based on the growing evidence, the attention bias for threat has been stated to have causal connections with etiology and the maintenance of anxiety symptoms (Morales et al., 2016; Van Bockstaele et al., 2014). In previous studies, also the lower maternal EA has been related to the child's internalizing symptoms (Biringen et al., 2014; Easterbrooks et al., 2012). Taking together the findings of the present study and this clinically-oriented framework, a question arises, if the heightened attention bias for fear is a maladaptive trait mediating the association between the lower maternal EA and child psychopathology.

Second, more recent models have argued that the heightened attention to fear is an adaptive trait in social contexts (Grossmann, 2022; Marsh, 2016). For example, in previous studies, the higher attention bias for fearful faces at 7–8 months of age has been related to positive social outcomes, such as the secure attachment (Peltola et al., 2015), helping behaviors (Grossmann et al., 2018; Peltola et al., 2015) and other social-emotional competencies (Eskola et al., 2023) during toddlerhood. These recent models have stated that the enhanced sensitivity to fearful faces, that is, the signs of other's distress and helplessness, is related to approaching behaviors, greater cooperative behaviors and altruism (Hammer & Marsh, 2015; Marsh, 2016, 2019). The developmental outcomes of the heightened attention bias for fear during infancy are an important topic of research in future and both positive and negative aspects need to be explored.

The previous study of general population by Taylor-Colls and Fearon (2015) showed an association between the composite score of maternal EA and the heightened neural responses to happy versus fearful faces at 7 months of age. In other words, their study found association between higher maternal EA and the facial expressions of positive valence while the present study found the association between lower maternal EA and facial expressions of negative valence. Although the findings are not in contradiction, there is a discrepancy between significant associations in the age groups very close to each other. Future studies may show, if this discrepancy can be explained, for example, by the rapid development of emotional attention patterns during infancy or the mismatch between behavioral and brain measures in children under 3 years of age (Xie et al., 2021; Yrttiaho et al., 2014).

Interestingly, we found no association between the EA and the general attention bias for faces versus the non-face stimuli. A general attention bias for faces has been prevalent among infants, but the studies on its connections to the environmental factors, such as maternal caregiving behaviors, are sparce (Johnson et al., 2015; Reynolds & Roth, 2018). It is possible that the association between the general attention bias for faces and the maternal EA would be seen in the tasks using more natural non-face stimuli (for example, toys or furniture) than the scrambled face used in this study. Also, as the average level of the maternal EA in all its subscales was relatively high in this study, exploring these associations among the mothers at a higher risk of lower EA would further the understanding of this phenomenon.

Our study has some limitations. Because of the cross-sectional study design in one cohort sample, no conclusions about the causal relations between the maternal caregiving behaviors and an infant's affect-biased attention can be drawn. In future, longitudinal data with comparable methods from other cohorts are needed. For example, a previous longitudinal, multisite study by Vallorani et al. (2023) demonstrated that maternal anxiety symptoms fluctuating between measurements were related to more stable attention patterns to both positive and negative facial expressions, here, happy and angry faces, in children between 4 and 24 months of age. In other words, longitudinal data provides crucial information about the associations between the development of affect-biased attention and the change in environmental factors. In addition, we did not account for the latent factors that may explain our findings, such as the effects of other environmental factors (e.g., family structure) or genetic factors that may be connected both to the maternal EA and to the infant's affect-biased attention. However, we controlled for maternal psychological distress that may influence an infant's social-emotional development through caregiving behaviors. Unfortunately, the number of missing reports of maternal depressive and anxiety symptoms was relatively high ($n = 26$ and $n = 25$, respectively). Still, future studies should seek to investigate the gene-environment interplay to determine the development of attention biases.

Moreover, we were not able to study the father–infant interaction, although there have been strong evidence demonstrating that fathers have a crucial role in child development (Möller et al., 2016). The research on fathers or mother–father–infant triads and the infant attention for faces remains an important focus for future studies.

Finally, maternal caregiving behaviors or maternal subtle reactions to the emotional face stimuli may have influenced an infant's fear processing during the eye-tracking experiment, as the infants were sitting on the mother's lap and the mothers were not blindfolded. However, the mothers were instructed not to comment on the emotional content of the faces in order to minimize the influence of the maternal presence on an infant's gaze behavior and the researcher also monitored the assessment.

5. Conclusions

Our results demonstrated that the lower maternal emotional availability is related to an infant's higher attention to fearful faces at 8 months of age. This finding indicates that the lower maternal emotional availability may sensitize an infant's emotion processing system and this association is seen at least during this specific age around 8 months. However, depending on the theoretical framework, the infant's heightened attention bias for fear may be seen as either an adaptive or maladaptive trait in the context of the lower quality of maternal caregiving behaviors. Therefore, the influence of caregiving behaviors on children's social-emotional well-being via children's affect-biased attention is an important topic for future research.

CRediT authorship contribution statement

Eeva Eskola, Writing – original draft. **Eeva-Leena Kataja**, Methodology, Investigation, Data curation, Funding acquisition, Writing – original draft. **Jukka Hyönä**, Supervision, Writing – review&editing. **Hetti Hakanen** Data curation, Writing – review&editing. **Saara Nolvi**, Investigation, Funding acquisition, Writing – review &editing. **Tuomo Häikiö**, Methodology, Software, Data curation, Writing – review&editing. **Juho Pelto**, Formal analyses, Writing – original draft. **Hasse Karlsson**, Conceptualization, Methodology, Funding acquisition, Writing – review&editing. **Linnea Karlsson**, Conceptualization, Methodology, Funding acquisition, Writing – review&editing. **Riikka Korja**, Supervision, Conceptualization, Funding acquisition, Writing – original draft.

Author note

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Data Availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.infbeh.2023.101900.

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