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Behavioral Regulatory Problems Are Associated With a Lower Attentional Bias to Fearful Faces During Infancy

Eeva Eskola
University of Turku and Turku University Hospital

Eeva-Leena Kataja, Jukka Hyönä, Tuomo Häikiö, and Juho Pelto
University of Turku

Hasse Karlsson, and Linnea Karlsson
University of Turku and Turku University Hospital

Riikka Korja
University of Turku

To investigate the role of early regulatory problems (RP), such as problems in feeding, sleeping, and calming down during later development, the association between parent-reported RP at 3 months (no-RP, n = 110; RP, n = 66) and attention to emotional faces at 8 months was studied. Eight-month-old infants had a strong tendency to look at faces and to specifically fearful faces, and the individual variance in this tendency was assessed with eye tracking using a face-distractor paradigm. The early RPs were related to a lower attention bias to fearful faces compared to happy and neutral faces after controlling for temperamental negative affectivity. This suggests that early RPs are related to the processing of emotional information later during infancy.

Behavioral regulatory problems (RP) are defined in the literature and in psychiatric diagnostic classifications, such as the DC 0–3, as excessive crying, sleeping, and feeding problems (Gross, 2016; Hemmi, Wolke, & Schneider, 2011, Zero to Three, 2016). These are the first indicators for a developmental risk, which can be observed in infant behavior (Gross, 2016; Hemmi et al., 2011). The estimated prevalence of behavioral RP varies from 5% to 20% (Hemmi et al., 2011; Thiel-Bonney & Cierpka, 2016). RP during the early years of development have been associated with pre- and postnatal neurophysiological and psychosocial risk factors, such as preterm birth, fetal abnormalities, family adversity, maternal anxiety, and maternal psychosocial stress (Papoušek & Von Hofacker, 1998; Schmid, Schreier, Meyer, & Wolke, 2011). During the very first months of infant life, crying, eating, and sleeping are more innate behaviors reflecting more the infant's individual characteristics and are not yet influenced by caregiving behaviors (Emde, 1998; Thiel-Bonney & Cierpka, 2016). After the "social awakening" at approximately 3 months of age, an infant's environment starts to have a greater influence on their regulatory behavior through their social interaction as a result of the maturing behavioral regulation and communication between the infant and the parent (Emde, 1998; Thiel-Bonney & Cierpka, 2016).

The concept of infant temperament, defined as individual differences in reactivity and self-regulation, overlaps to some extent with RP, as fussing, crying, and falling asleep with ease, for instance, also fall under the negative reactivity dimension of temperament (Rothbart & Derryberry, 1981). Whereas RP are seen as more transient features of infant behavior (Jusiene, Breidokiene, & Pakalniskiene, 2015; Schmid, Schreier, Meyer, & Wolke, 2010), temperament reflects more stable differences between individuals, even though temperamental

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Correspondence concerning this article should be addressed to Eeva Eskola, FinnBrain Birth Cohort Study, University of Turku, Lemminkäisenkatu 3, 2. floor, 20520 Turku, Finland. Electronic mail may be sent to epesko@utu.fi.

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regulation undergoes changes during the early development (Bridgett, Burt, Edwards, & Deater-Deckard, 2015; Rothbart, Sheese, Rueda, & Posner, 2011). During infancy, the concept of temperament includes a normal variation of emotional positive and negative reactivity and regulation covering approach-avoidance behavior, attention mechanisms, and self-soothing behaviors (Rothbart & Derryberry, 1981). RP, in turn, refer to problem behaviors and cover regulatory behavior more broadly, including regulation of physiological functions (i.e., eating and sleeping; Gross, 2016).

The connections between RP persisting after 3 months of age and the emergence of psychiatric problems, such as internalizing and externalizing symptoms and also attention deficit hyperactivity disorder (ADHD) later during childhood, are well established (Hemmi et al., 2011; Korja et al., 2014; Santos, Matijasevich, Capilheira, Anselmi, & Barros, 2015; Schmid & Wolke, 2014; Smarius et al., 2017). Previous studies of the predictive role that early RP play in child early development have mainly focused on the associations between early RP and infant temperament (Pauli-Pott, Becker, Mertesacker, & Beckmann, 2000; Toffol et al., 2019). The predictive role of the very early RP in other psychological developmental areas is still unknown. Biased cognitive processing of emotional information may be one of the critical pathways in how genetic and environmental risk factors influence psychological well-being, as several lines of research have noted a role for negative cognitive biases, such as threat-related bias, in self-regulation and mental health (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Fox & Beevers, 2016). One possibility to further understand the developmental effects of early RP is to study individual variance in cognitive biases, especially attention biases, in processing emotional information during infancy, at the time when these biases first emerge. In addition, observed attention biases would provide a more objective perspective to the possible outcomes of RP, as previous studies have used mainly parental reports.

Only a few studies have investigated the connection between RP and infant attention capacities, even though control of attention and particularly the efficiency of attention disengagement and shifting have been considered the first forms of infant self-regulation and, more specifically, emotion regulation (Bridgett et al., 2015; Posner, Rothbart, Sheese, & Voelker, 2014; Rothbart et al., 2011). An infant's ability to disengage their attention from distressing objects in the environment is among the first self-soothing behaviors that can be observed behaviorally (Field, 1981; Lewkowicz & Turkewitz, 1981; Rothbart et al., 2011). In previous studies, an infant's overall ability to disengage their attention from one stimulus to another is related to their better regulation of negative emotionality, as measured as parent-reported soothability (Crockenberg & Leerkes, 2004; Johnson, Posner, & Rothbart, 1991; Leppänen et al., 2011; Nakagawa & Sukigara, 2019b). Infant soothability also has a predictive role in the development of neural attention networks responsible for attention orienting and attention shifting, as higher levels of soothability at 7 months of age predicted more efficient brain networks that underlie attentional orienting at 7 years of age (Posner et al., 2014). As attentional disengagement has been found to be related to infant soothing behaviors, early behavioral RP might be related to the ability for attention disengagement during infancy, and this is the focus of this study. This is an important topic, as individual variance in the overall probability of attention disengagement may form a link between infant RP and early self-regulation difficulties.

Another important attention-related aspect of self-regulation, affect-biased attention, refers to the perceptual preference for an object based on its relative affective salience (Todd, Cunningham, Anderson, & Thompson, 2012). Todd et al. (2012) suggest that affect-biased attention is itself emotion regulation, as it shapes the information received from the environment and, therefore, shapes the emotional response to the given situation. Affect-biased attention is shaped by different subcomponents of general attention, such as individual differences in attentional orienting, maintenance, and disengagement when processing emotional stimuli (Fu & Pérez-Edgar, 2019; Morales, Fu, & Pérez-Edgar, 2016). The attention biases have been explained by their biological relevance, as the human information processing capacity is limited, and a human's perceptual systems need to select the information most relevant to survival and other goals (Öhman & Mineka, 2001; Pessoa & Adolphs, 2010). For instance, behavioral studies in adults have shown an attentional preference for social signals of fear, such as fearful facial expressions, that may indicate a threat in the environment (Georgiou et al., 2005; Leppänen & Nelson, 2009; Pourtois, Grandjean, Sander, & Vuilleumier, 2004).

During human development, affect-biased attention is related to socioemotional functioning, as it shapes the type of information an individual receives from the environment (Morales et al., 2016). Already, newborn infants show an attention bias toward social signals (Johnson, Senju, & Tomalski, 2015), for instance, by orienting toward happy facial expressions over negative ones, and this bias likely has a role in facilitating bonding between a caregiver and an infant (Farroni, Menon, Rigato, & Johnson, 2007). After 7 months of age, infants still show an attention bias to faces (Amso, Haas, & Markant, 2014; Frank, Vul, & Johnson, 2009; Frank, Vul, & Saxe, 2012; Libertus, Landa, & Haworth, 2017). However, the attention bias to happy faces is no longer seen. Instead, infants start to show a robust bias for fearful faces versus happy or neutral ones, that is, a fear bias, demonstrating the role that this specific feature of attention plays as part of the normal development of face processing during the second half of the first year (Leppänen, Cataldo, Enlow, & Nelson, 2018; Peltola, Leppänen, Palokangas, & Hietanen, 2008; Yrttiaho, Forssman, Kaatiala, & Leppänen, 2014). Attention bias to fear emerges when the processing of social signals of fear and distress in others becomes relevant in relation to other developing skills (Bertenthal & Campos, 1984; Bowlby, 1969; Leppänen & Nelson, 2012). The emergence of this bias occurs at the same time or just before the start of an infant's independent mobility and exploration of their world (Leppänen & Nelson, 2012). In parallel, the development of attachment with selected other people (e.g., the parents) strengthens, while friendly, undiscriminating responses to everyone else wanes (Bertenthal & Campos, 1984; Bowlby, 1969). This fear bias has been studied, for instance, with an emotional overlap paradigm during infancy, in which centrally presented fearful faces have been found to decrease the probability of attention disengagement toward a lateral distractor stimulus compared to centrally presented neutral or happy faces (Peltola et al., 2008).

While some aspects of affect-biased attention are part of the normative development, others have been connected to psychiatric symptoms during later childhood and adulthood (Fu & Pérez-Edgar, 2019). A well-established example is a heightened attention bias to threat in anxiety disorders (Bar-Haim et al., 2007; Morales et al., 2016). A recent eye-tracking study in infants demonstrated an association between lower attention bias for threat and lower temperamental negative affectivity, which is known as a temperamental risk factor for psychiatric symptoms during later childhood (Pérez-Edgar et al., 2017). It is still unclear, however, if behavioral RP are associated with variance in these early-emerging socioemotional attention biases. Thus, our aim was to study how early RP are related to alterations in early, age-relevant attention biases through an attention bias to faces and specifically to fearful faces.

In summary, solid evidence exists indicating that the behavioral RP are related to socioemotional development and behaviors later during childhood (Hemmi et al., 2011; Korja et al., 2014; Santos et al., 2015; Schmid & Wolke, 2014; Smarius et al., 2017). In addition, attention biases have been related to psychiatric symptoms, such as anxiety in children, adolescents, and adults (Bar-Haim et al., 2007; Shechner et al., 2012), and biased attention patterns may be one of the critical pathways how genetic and environmental risk factors influence psychological well-being (Fox & Beevers, 2016). However, little is known about how early RP are related to the early development of attention patterns.

In this longitudinal exploratory study, we investigated how early parent-reported behavioral RP, for example, in feeding, sleeping, and soothing behavior, are associated with attention disengagement from facial expressions of emotion, particularly fear, later during infancy. More specifically, we studied whether the RP at 3 months are related to the infant's attention disengagement from facial expressions of emotion toward distractors, as measured with eye tracking combined with an overlap paradigm (e.g., Aslin & Salapatek, 1975; Peltola et al., 2008) at the age of 8 months. We chose to focus on the attention disengagement of all subcomponents of attention because the attention-orienting network that underlies attention disengagement is the dominant attention network during infancy responsible for processing sensory stimuli and self-regulation (Peltola et al., 2008; Posner et al., 2014). We chose to use facial expressions as emotional targets, as emotional information of other peoples' states is relevant in relation to other developmental aspects during the second half of the first year (Bertenthal & Campos, 1984; Bowlby, 1969; Leppänen & Nelson, 2012). As maternal pre- and postnatal depressive symptoms (Forssman et al., 2014; Kataja et al., 2018) and anxiety symptoms (Jones, Slade, Pascalis, & Herbert, 2013; Kataja et al., 2019; Morales et al., 2017) have been related to individual variation in attention bias to faces and particularly to fearful faces (Forssman et al., 2014; Jones et al., 2013; Kataja et al., 2018, 2019; Morales et al., 2017), we controlled for the effects of postnatal maternal and paternal depressive and anxiety symptoms. In addition, the effect of infant temperamental negative affectivity was controlled for in the analyses, as we assumed that RP are an independent predictor of later development despite their overlapping features with temperament. Our study questions were as follows: (a) How are the parent-reported RP at the age of 3 months associated with the overall probability of attention disengagement from central visual stimuli to salient lateral distractors at the age of 8 months? and (b) How are RP at the age of 3 months associated with either the attention bias to faces or the attention bias to fearful faces at the age of 8 months, as both the bias to faces and particularly to fearful faces should be prevalent at this age? To our knowledge, this is the first study to investigate the association between RP and an infant's attention to emotional faces. As the sample size is relatively small and no assumptions were made of the direction of the associations, this study represents an exploratory effort.

Method

Participants

The participants ($n = 176$), all European, belonged to a larger FinnBrain Birth Cohort study ($n = 3{,}808$, www.finnbrain.fi) examining the effects of early-life distress on child development. The main cohort sample represents the source population of Finland (Karlsson et al., 2018). The recruitment for the main cohort took place in South-Western Hospital District and Åland Islands in Finland between December 2011 and April 2015. The mothers and their spouses were recruited by a research nurse at the first trimester ultrasound visit at gestational week (gwk) 12. A verified pregnancy and sufficient knowledge of either Finnish or Swedish, being the official languages of Finland, were required.

The infants of this substudy belonged to the Focus Cohort, a subsample that was established to study, in more detail, the effects of early-life distress on an infant's development. The Focus Cohort Criteria were based on preliminary cohort data analyses using the first 500 mothers' questionnaire data on prenatal depressive, general anxiety, and pregnancy-related anxiety symptoms at gwk 14, 24, and 34. The Focus Cohort was comprised of two groups of mothers and their families, which were mothers who reported elevated distress in at least two different prenatal assessments and their controls being those who had low self-reported symptoms at each assessment. The Focus Cohort Criteria are described in detail in Karlsson et al. (2018). The study protocols of the FinnBrain Birth Cohort Study were granted approval by the Ethics Committee of the Hospital District of Southwestern Finland. The study was conducted in full compliance with the Helsinki Declaration.

Study Visit at the Age of 8 Months

This study is part of the Child Development and Parental Functioning Lab substudy, which was established to examine with experimental measures the development of self-regulation in the context of early-life distress. The families of the Focus Cohort were invited to take part in an intensive child development follow-up, including a study visit, when their infant was at the age of 8 months. This visit included an assessment of the infant's attention with eye tracking, an assessment of the mother–infant interaction during free play, and an assessment of the infant's temperament and executive functions. The visits were carried out in the FinnBrain laboratories at the University of Turku between March 2013 and July 2016. The visits were led by either psychologists or advanced psychology students. The researchers were blinded to the participants' RP.

We attempted to contact 908 Focus Cohort families by phone about the study visit. Contact was made with 676 (74.4%) families, of which, 526 (77.8%) agreed to participate. Finally, 446 (66.0% of the contacted and 84.8% of those who initially agreed) infants participated in the laboratory visit, in which 421 eye-tracking measurements were conducted. Of the initial 421 eye-tracking measurements, 31 (7.4%) failed to provide data (i.e., the infants were too fussy or the data were invalid due to technical problems). Of the final 390 measurements, 363 (93.1%) met the quality criteria described later. In addition, infants born before gwk 37 ($n = 13$, 3.6%) were excluded to limit the possibly confounding effects of prematurity. Of this group, 304 maternal reports and 187 paternal reports of the RP of the infants at the age of 3 months were available. Finally, the group of 176 infants with both parents' reports was used for our main analyses. This group's data partially overlapped with the data presented in Kataja et al. (2018, 2019, 2020) and Tuulari et al. (2020).

Measures

Background Factors

Family and infant background characteristics were obtained from questionnaires completed by parents (gwk 14, 24, and 34; 3 months of age), which included information about the mother's language, the parents' education, their monthly income, parity, and whether both parents were living in the same household with the child. Information about infant characteristics (the infant's sex, gwk at birth, birth weight, and Apgar score at the age of 5 min) was drawn from the Finnish Medical Birth Register administered by the National Institute for Health and Welfare (www.thl.fi). Maternal and paternal depressive symptoms were measured with the Edinburgh Postnatal Depression Scale (EPDS; Cox, Holden, & Sagovsky, 1987) and the anxiety subscale of the Symptom Checklist-90 (SCL-90; Holi, Sammallahti, & Aalberg, 1998), when the infants were at the age of 3 months. Infant temperament was measured with the Infant Behavior Questionnaire Revised (IBQ-R; Gartstein & Rothbart, 2003) at the age of 6 months and, if available, both parents' reports were used. The dimension of "Negative Affectivity" was used in the analysis as a continuous variable.

Early RP

The questionnaire data on parental concerns about early regulation behaviors at the age of 3 months were used to measure early RP. The questions asking about the problems were "Have you experienced difficulties or have you been worried about the following things and if so, how much? (a) The feeding your infant, (b) The sleeping of your infant, and (c) The comforting and calming of your infant." The options for the answers were "no problems," "some problems," and "a considerable number of problems." To control for a possible reporting bias, both parental reports were used. The distribution of parental reports is presented in Table 1. The measure for RP (i.e., RP group; n = 66; 37.5%) was defined as multiple or high levels of problems ("some problems" in both parents' reports in any of the three domains or "a considerable number of problems" in one of the parents' reports in any of the three domains). Otherwise, "no RP" was applied (i.e., no-RP group; n = 110; 62.5%). Table 1 presents the percentages of parent-reported RP for the whole sample and for the RP and no-RP groups separately. The descriptive statistics of infant and parent characteristics are presented in Table 2. Maternal (n = 309) and paternal (n = 187) reports of concurrent psychological distress symptoms were associated with their reports of their infant's RP. Parents reporting "some problems" in multiple domains or "a considerable number of problems" in one domain had higher levels of concurrent anxiety symptoms (SCL-90, mothers: n = 114, M = 3.34, 95% CI [2.59, 4.10]; fathers: n = 47, M = 3.26, 95% CI [2.10, 4.41]) and depressive symptoms (EPDS, mothers: M = 5.26, 95% CI [4.52, 6.00]; fathers: M = 4.33, 95% CI [3.07, 5.60]) than parents reporting fewer problems (SCL-90, mothers: n = 195, M = 2.03, 95% CI [1.52, 2.53]; fathers: n = 140, M = 2.14, 95% CI [1.56, 2.72]; EPDS mothers: M = 3.11, 95% CI [2.63, 3.58], fathers: M = 3.02, 95% CI [2.47, 3.57]). We used both parents' reports of the RP in the analyses.

Table 1
The Regulatory Problems (RP) of Infants at 3 Months of Age Reported by Mothers and Fathers

	All participants (n = 176) %			RP (n = 66) %			No RP (n = 110) %		
Categories[a]	1	2	3	1	2	3	1	2	3
Maternal report of problems									
Feeding	56	38	6	26	58	17	75	26	0
Sleeping	60	38	2	26	68	6	80	20	0
Calming down	67	32	1	35	62	3	86	14	0
Paternal report of problems									
Feeding	77	22	1	49	49	3	94	6	0
Sleeping	69	30	1	38	59	3	88	12	0
Calming down	69	31	0	39	61	0	86	14	0

[a]Scoring description: 1 = no problems, 2 = some problems, 3 = a considerable number of problems.

Attention to Facial Expressions as Measured by Eye Tracking

Procedure

During eye tracking, infants were seated on either of their parent's lap in a dimly lit room at a 50–70 cm distance from the eye tracker (Desktop Mount, EyeLink1000+, SR Research Ltd., Toronto, Ontario, Canada). Infants viewed the stimuli on a screen placed 15 cm behind the tracker. The researcher conducted the tracking with a host computer in the same room behind a curtain. A 5-point calibration routine was performed followed by a validation, which was repeated during the experiment if needed. The x- and y-coordinates for the estimated gaze location were recorded at a frequency of 500 Hz.

We used an overlap paradigm (Aslin & Salapatek, 1975; Peltola et al., 2008) to examine the infant's attention disengagement from a centrally presented facial expression or a scrambled face

Table 2
The Descriptive Statistics of the Child and Parental Characteristics

	All participants n = 176	Regulatory problems (RP) n = 66 (37.5%)	No RP n = 110 (62.5%)
Child characteristics			
Sex (boys), %[a]	47.2	45.5	48.2
First-borns, %[a]	65.3	77.3	58.2
Both parents in the same household, %	98.8	98.5	98.2
Birth phenotype			
Gestational weeks at birth, *M* (*SD*)	40.11 (1.17)	40.05 (1.14)	40.14 (1.19)
Birth weight, *M* (*SD*)	3,616.46 (459.16)	3,660.30 (472.04)	3,590.15 (451.37)
Apgar score at 5 min, median (range)	9 (4–10)	9 (4–10)	9 (4–10)
Temperamental negative affectivity at 6 months[a]		3.17 (0.69) (n = 60)	2.88 (0.74) (n = 98)
Parental characteristics			
Maternal distress at 3 months			
EPDS, *M* (*SD*)[b]	3.65 (3.53)	4.74 (3.54)	3.00 (3.38)
SCL-90/anxiety, *M* (*SD*)[b]	2.34 (3.66)	3.17 (4.15)	1.85 (3.25)
Paternal distress at 3 months			
EPDS, *M* (*SD*)[b]	3.27 (3.54)	4.27 (4.29)	2.67 (2.86)
SCL-90/anxiety, *M* (*SD*)[b]	2.38 (3.67)	3.44 (4.71)	1.75 (2.69)
Maternal			
Education			
< 12 years	26.7%	19.7%	30.9%
12–15 years	33.5%	34.8%	32.7%
> 15 years	39.8%	45.5%	36.4%
Paternal			
Education			
< 12 years	38.1%	30.3%	44.8%
12–15 years	35.8%	40.9%	34.3%
> 15 years	23.3%	28.8%	21.0%
Monthly income (median)	2,001–2,500€	2,001–2,500€	2,001–2,500€

Note. EPDS = Edinburgh Postnatal Depression Scale; SCL-90 = Symptom Checklist-90.
[a]Statistically significant difference between RP and no-RP groups, χ^2-test, $p < .05$. [b]Statistically significant difference between RP and no-RP groups, Mann–Whitney U-test, $p < .05$.

control stimulus to a lateral distractor (Figure 1). The face stimuli were color images (15.4° × 10.8°) of facial expressions with a white background. Pictures adopted from the study of Peltola et al. (2008) presented two women posing with neutral, happy, and fearful facial expressions and a scrambled face control stimulus. The distractors were black and white checkerboards and vertically arranged circles (15.4° × 4.3°).

An audio-visual animation preceded every trial to capture the infant's gaze at the center of the screen. During the 4,000 ms trials, the happy, fearful, or neutral face or the control stimulus was presented in a semi-random order in the center of the screen so that all of the stimuli were presented six times but no more than three times in a row. After 1,000 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 3,000 ms. The lateral stimulus was presented on the same side of the screen no more than three times in a row. The measurement consisted of two sets of 24 trials (six trials per condition per set) with a small break with 4 s animations between sets. If an infant was restless, little breaks were held during the measurement. The eye tracking was stopped if the infant became seemingly inattentive or fussy.

Gaze Acquisition and Raw Data Processing

The eye-tracking data included timestamps for the onset times of central and lateral stimuli in addition to the x- and y-coordinates of the participant's gaze position. We analyzed the data offline using the library of Matlab (Mathworks, Natick, MA) scripts (Leppänen, Forssman, Kaatiala, Yrttiaho, & Wass, 2015) that were designed to cope with the challenges of analyzing data collected from

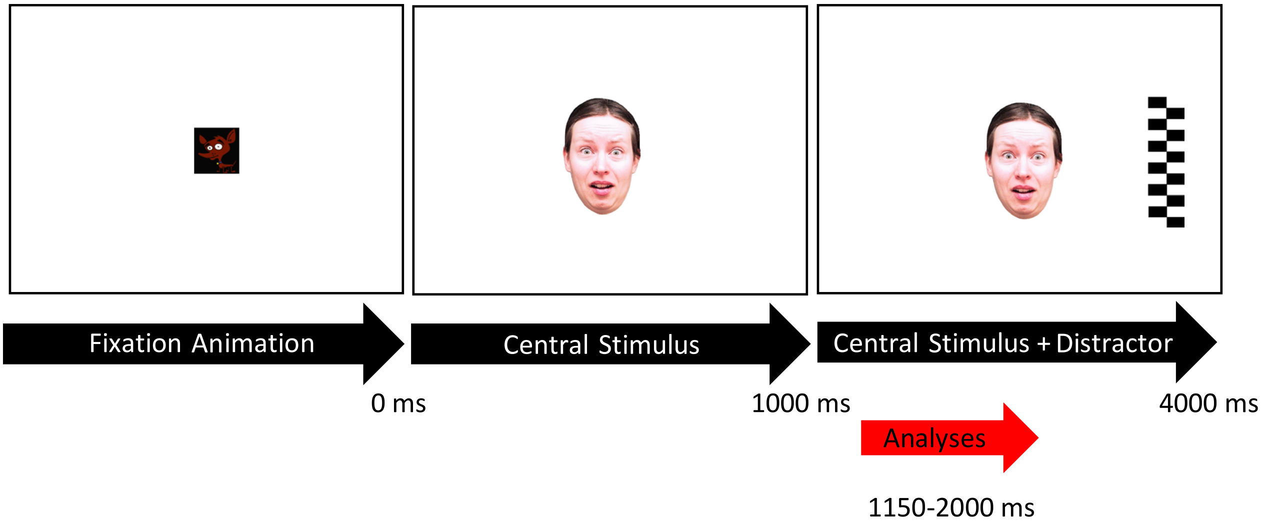

Figure 1. An overlap paradigm: timeline for presenting the targets and for the analysis period.

poorly cooperating participants. Gaze shifts from the central stimulus to the lateral distractor were analyzed between 150 and 1,000 ms after the appearance of the lateral distractor (i.e., the analysis period was set from 1,150 to 2,000 ms after the onset of the trial) to measure reactive attention shifts toward the distractors, as has been done in previous studies using the same protocol (Kataja et al., 2018, 2019; Peltola, Yrttiaho, & Leppänen, 2018; Yrttiaho et al., 2014). A trial was considered valid if it met three inclusion criteria being, (a) a fixation on the central stimulus over 70% of the time before gaze disengagement or before the end of the analysis period, (b) no gaps longer than 200 ms in the samples of the gaze data, and (c) no missing gaze data during gaze disengagement. Infants with valid data from at least three trials per condition were included in the final analyses.

Eye-Tracking Variables

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. It was coded as 0 = no disengagement and 1 = disengagement. Invalid trials were treated as missing values.

Estimated Quantities

Values of the following eye-tracking quantities for a representative infant were estimated using the mixed effects logistic regression (MELR) models described in the next section. Disengagement probability (DP) was defined as the infant's probability for disengaging his or her attention from the central stimulus to the lateral distractor, that is, DP was roughly the ratio between the number of trials with disengagement and the number of all valid trials in a hypothetical sequence of infinitely many trials. Fear bias was defined as the ratio of an infant's geometric mean odds of disengaging from the happy and neutral conditions to the odds of disengaging from the fearful condition. That is, the fear bias was positive, if the DPs for the neutral and happy conditions were higher than for the fearful condition (Kataja et al., 2018, 2019). The face bias was defined in a similar way as fear bias but compared the DP of the control stimulus to the DPs of the happy or neutral condition, that is, if the DP for the control stimulus was higher than the DPs for the happy or neutral condition, the face bias was positive (Kataja et al., 2018, 2019).

Statistical Analysis

Due to the lack of previous research, we made no assumptions of the directions of the associations and our analyses are exploratory. DPs were modeled using MELR models with the binary disengagement variable (disengagement or no disengagement) as the response variable. All of our MELR models had condition 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 all our models. The trial number dependency was modeled by a natural cubic spline with one cutoff point between trials 24 and 25 (see Kataja et al., 2018, for the discussion on the trial number dependency as well as the general features of the attention patterns in this sample of infants).

To analyze the differences in the overall DPs between the RP groups (Study Question 1), we used a model (Model 1; Figure 2a) in which the fixed effects were:

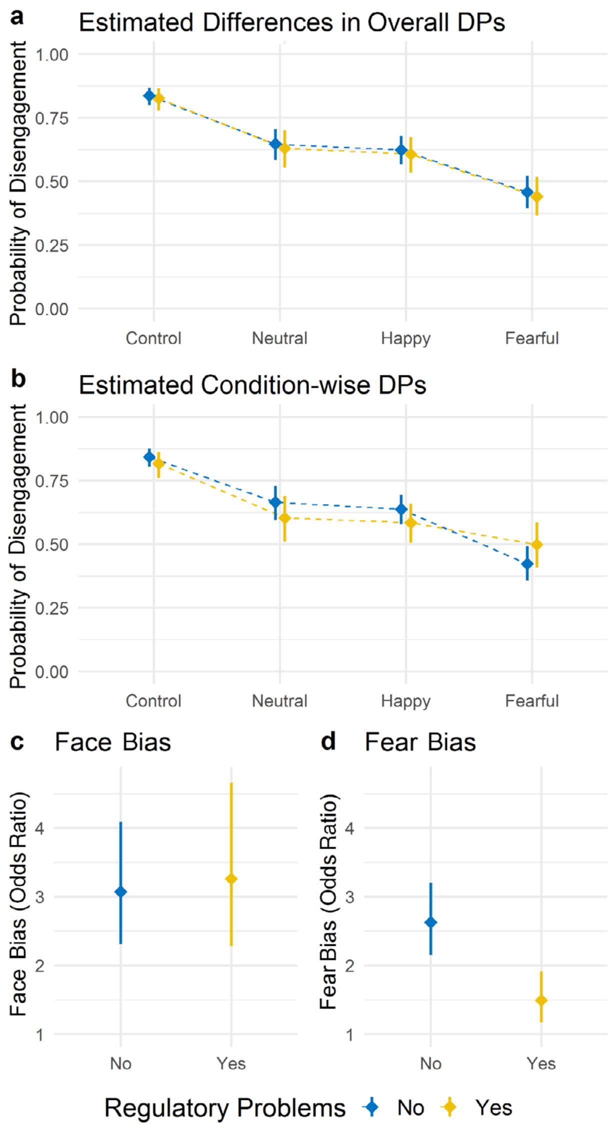

Figure 2. (a) Estimated disengagement probabilities (DP) from Model 1 without the trial number in the regulatory problem (RP) groups: no and yes (b) DPs for the control stimulus condition and neutral, happy and fearful face condition in the RP groups: no and yes. (c) Odds ratio for the face bias in the RP groups: no and yes. (d) Odds ratio for the fear bias in the RP groups: no and yes. In all the figures, the error bars represent 95% confidence intervals.

$$\text{Condition} + \text{RP} + \text{TNS}[+\text{Control variables}],$$

where Condition was a categorical variable with four values, being neutral, happy, fearful, and control; TNS referred to the two trial number spline terms; and RP was a binary variable for the two RP groups. Control variables were the maternal and paternal SCL-90 and EPDS scores at 3 months postpartum and the dimension of “Negative Affectivity” from the IBQ-R questionnaire at the age of 6 months that were included to control for parental stress and the child temperamental negative affectivity. The $n = 35$ missing values in the negative affectivity variable were inputted with the median.

To analyze the differences in fear bias and face bias (Study Question 2), we used a model (Model 2) including the fixed effects:

$$\text{Condition} + \text{RP}[+\text{Control variables}] + \text{Condition} \times (\text{RP}[+\text{Control variables}]) + \text{TNS}.$$

Here, we used contrast codings for Condition that allowed us to compare the average of the happy and neutral conditions to the fear condition (i.e., fear bias) or to compare the average of the happy and neutral conditions to the control stimulus (i.e., face bias). Our study questions were then answered by a contrast-coded Condition × RP interaction term. Model 2 without the TNS terms was also used to calculate the predicted condition-wise, trial-number-independent DPs, and their confidence intervals given in Table 3 and Figure 2b.

All of the statistical analyses were performed in R 3.5.2 (R Core Team, 2018) using package lme4 (Bates, Mächler, Bolker, & Walker, 2015) for running the MELR models and package ggplot2 (Wikham, 2009) to create Figure 2.

Table 3

The Trial-Number Independent Disengagement probabilities (DPs) for the Face Stimuli and Control Stimulus. Odds Ratios (OR) for the Fear Bias and the Face Bias. p *Values for Comparisons Between the Regulatory Problem (RP) Groups*

	RP DP/OR [95% CI]	No RP DP/OR [95% CI]	*p* value
Control picture	0.82 [0.76, 0.86]	0.84 [0.80, 0.88]	.40
Neutral face	0.60 [0.51, 0.69]	0.66 [0.60, 0.73]	.28
Happy face	0.58 [0.51, 0.66]	0.64 [0.58, 0.69]	.28
Fearful face	0.50 [0.41, 0.59]	0.42 [0.36, 0.49]	.19
Fear bias	1.50 [1.17, 1.91]	2.62 [2.16, 3.20]	.00046
Face bias	3.26 [2.28, 4.66]	3.07 [2.23, 4.09]	.80

Results

Disengagement Probabilities in the Whole Infant Sample

The DPs in the whole eye-tracking sample ($n = 363$) were reported previously by Kataja et al. (2018). In this study, the study sample comprised of 176 infants, whose parents had given reports of RP at the infant's age of 3 months. The estimated DPs from Model 2 of both RP groups ($n = 176$) resembled the attention patterns of the whole infant sample ($n = 363$). The DPs were highest for the control stimuli, intermediate for the neutral and happy faces, and lowest for the fearful faces (Table 3). This finding shows that the age-typical fear bias was also present in this infant sample (e.g., Leppänen et al., 2018; Nakagawa & Sukigara, 2019a; Peltola et al., 2008).

Overall Disengagement Probabilities for Two Groups of RP

Using Model 1, we analyzed how overall DPs differed between the RP group and no-RP group (Figure 2a). There was no statistically significant difference in the overall DPs between the groups (OR = .95, 95% CI [0.66, 1.37], $p = .79$) even when controlling for the parental anxiety symptoms, depressive symptoms, and infant temperamental negative affectivity (OR = .86, 95% CI [0.59; 1.27], p=.45). Using Model 2, we analyzed how the DPs differed between the groups by the stimulus condition (i.e., scrambled, neutral, happy, and fearful faces). The differences in DPs between the groups were not statistically significant for any stimulus condition (Table 3 and Figure 2b).

Attention Bias to Faces and Fearful Faces for the Two Groups for RP

Using Model 2, we studied how the RP were associated with attention biases (i.e., the face bias and the fear bias). Table 3 shows the estimated odd ratios for face bias and fear bias. There was no statistically significant difference in the face bias between the groups of the RP (Figure 2c and Table 4). However, the fear bias was significantly lower in the RP group than in the no-RP group. The difference remained significant after controlling for the parental concurrent depressive and anxiety symptoms and the infant temperamental negative affectivity at 6 months (Table 4). The difference between DPs in the fear condition, as opposed to the happy and neutral conditions, was lower in the RP group than in the no-RP group (Figure 2d). In other words, the infants with RPs demonstrated a lower attention bias to fearful faces as opposed to other faces than the infants with no RPs.

Table 4
The Comparisons of the Fear and Face Biases Between the Regulatory Problems (RP) Groups

Comparison of RP groups	Ratio of fear bias ORs [95% CI]	Ratio of face bias ORs [95% CI]
No versus yes	1.76 [1.28, 2.41]	0.94 [0.60, 1.49]
No versus yes, with prenatal distress controlled	2.03 [1.47, 2.81]	0.82 [0.51, 1.32]

Discussion

Our aim for this study was to investigate the association between parent-reported RP of their infants at 3 months of age and the laboratory-assessed attention to emotional faces at 8 months of age. RP after 3 months of age have been related to externalizing and internalizing problems and ADHD later during childhood (Hemmi et al., 2011; Korja et al., 2014; Santos et al., 2015; Schmid & Wolke, 2014; Smarius et al., 2017). However, the role that early RP play before 3 months of age is still under debate (Toffol et al., 2019). Therefore, our interest was to examine how these early RP associate with the core features of infant socioemotional attention, namely a bias for faces and expressions of fear. The RP were defined as multiple problems in sleeping, feeding, or calming down or "a considerable number of problems" in any of them as reported by both parents. We used an overlap paradigm to study an infant's overall probability of attention disengagement from centrally presented face stimuli to lateral distractors as well as their attention bias to faces and specifically to fearful faces. Typically, infants at this age show a robust bias to faces and specifically to fearful faces (Leppänen et al., 2018; Peltola et al., 2008; Yrttiaho et al., 2014).

We found that infants with RP showed a lower attention bias to fearful faces than infants without RP. The effect was significant even after controlling for the maternal anxiety and depressive symptoms and the infant temperamental negative affect, indicating an independent role played by early RP in predicting a lower fear bias. We did not observe statistically significant differences in the overall probability of attention disengagement or in the face bias between the two groups. Thus, our results suggest that the early-emerging bias to faces is also present among infants with early RP at the age of 8 months.

We propose two possible explanations for the finding showing the association between early RP and a lower fear bias being due to a developmental delay account and an arousal account. According to the developmental delay account, the lower fear bias at the age of 8 months in the infants with RP may reflect a delayed or altered development of affect-biased attention. At the age of 8 months, the fear bias has just emerged, and even a short delay in development may result in a lower or missing fear bias. An attention bias to fearful faces emerges in normal development between 5 and 7 months of age slightly before or at the same age as other fear-related behaviors (Leppänen et al., 2018; Leppänen & Nelson, 2012; Peltola, Leppänen, Mäki, & Hietanen, 2009). The emergence of a fear bias is likely related to the developmental period, when infants start to explore their environment and read from other people's faces for social cues, such as signals of danger (Bertenthal & Campos, 1984; Leppänen & Nelson, 2012). One possibility is that both RP and the lower fear bias reflect a slower or altered pace of neural maturation. However, the neural correlates behind the development of RP and attention bias to fear have been less studied. Therefore, whether they share common neural networks is not yet known, but we propose two hypotheses of neural correlations behind the developmental delay account.

One hypothesis is that a delay or difference in development of the amygdala's structure, function, or connectivity is behind both RP and lower fear bias. The amygdala is well known for its key role in processing salient emotions such as fear (LeDoux, 2012); therefore, the amygdala development may underlie the individual differences in a fear bias. To our knowledge, no previous studies have connected differences in amygdala structure or function to very early RP. However, the amygdala is relatively mature at birth and, thus, exerts a heavy influence on infant reactivity until the maturation of prefrontal cortical areas that, in connection with the amygdala, start to downregulate amygdala activity and emotional reactivity during the first year of life (Nordahl & Schumann, 2019). More mature functional within-hemisphere connectivity between the amygdala and executive control network during toddlerhood predicts better emotion regulation at 4 years (Salzwedel et al., 2019). In addition, altered amygdala structure and function have been related to many psychiatric disorders, including anxiety disorders (Nordahl & Schumann, 2019) and, therefore, may be related to an infant's RP that are associated during later childhood with internalizing symptoms, including anxiety symptoms (Hemmi et al., 2011).

Another hypothesis is that a delay in the development of the attention-orienting network is behind RP and a lower fear bias. The electroencephalogram study of Yrttiaho et al. (2014) suggests that during the emergence of a fear bias between 5 and 7 months of age, the fear-sensitive cortical posterior activity becomes better defined and more consistent. The cortical posterior areas have also been related to the attention-orienting network, and deviances in this network, including defects in dorsolateral prefrontal cortex, parietal, and cerebellar areas, have been related to attention deficits in ADHD (Hart, Radua, Nakao, Mataix-Cols, & Rubia, 2013; Posner et al., 2014), which, in turn, have been strongly associated with early RP (Hemmi et al., 2011). It is also possible that a delay in the emergence of fear-processing capacities supports infants having more RP and reflects an adaptation to the risks that these problems cause. Before the emergence of a fear bias, infants show an attention bias to happy faces (Nakagawa & Sukigara, 2019a), and it has been speculated that during the first half of the first year, difficulties in detecting fear and danger may facilitate the infant's attachment to their caregiver (Leppänen & Nelson, 2012). A delay in the emergence of the fear bias may thus prolong the sensitive period for attachment formation in infants with RP.

According to the arousal account, the lower fear bias among the group of infants with RP may reflect their higher levels of arousal. A prior study of Woody et al. (2019) has shown a link between attention and arousal in children by measuring event-related potential and respiratory sinus arrhythmia. There are two alternative explanations for how arousal can be linked with a lower fear bias. First, arousal may increase vigilance toward the environment, specifically in the fearful face condition. Although the attention bias toward fearful faces is well established in infants during the second half of the first year (Leppänen et al., 2018; Peltola et al., 2008; Yrttiaho et al., 2014), at least in some subgroups of infants, fearful faces may facilitate attentional shifting and visual search (Kleberg, del Bianco, & Falck-Ytter, 2018; Morales, Pérez-Edgar, & Buss, 2015; Nakagawa & Sukigara, 2019a). Using a visual cuing paradigm, Nakagawa and Sukigara (2019a) found that seeing a fearful face, but not happy or neutral ones, enhanced the subsequent visual searching for peripheral targets. It may be that fearful faces, as signals of the presence of a possible biologically relevant threat, may enhance vigilance toward the environment to obtain information about the source of the threat (Marsh, 2016; Whalen, 1998). Applied to our results, fearful faces may lead to a higher arousal in infants with RP and, therefore, enhance vigilance toward lateral distractors, specifically in the fear condition. This, then, may lead to a lower fear bias in infants with RP. In addition, a dysregulated fear (i.e., a fearful temperament denoted by high levels of fear in both high- and low-threat situations) has been related to a lower attention bias to signals of threat (e.g., angry faces), which has been interpreted as a bias away from threat in this subgroup (Morales et al., 2015). In a previous study, an infant's stress reactivity measured through their heart rate response to watching a stressful video was related to shorter look durations and novelty preference (de Barbaro, Clackson, & Wass, 2016). In our study, it is possible that an infant's arousal increased only in the fearful condition in the infants with RP, and consequently, the fearful face increased novelty seeking and the probability of attentional disengagement from fearful faces to the lateral distractor. Therefore, a lower attention bias to fearful faces was detected.

Arousal may also affect the probability of disengagement in all face conditions. Arousal has been linked to increased speed in visual orienting, and moreover, unselective attentional responses meaning that salient fearful face stimuli are less likely to be emphasized among other face stimuli when arousal is high (Kleberg et al., 2018). It may be that the general arousal levels of the infants with RP were increased by the study visit, and the eye-tracking procedure and, therefore, the salient stimuli, that is, fearful faces, did not lower their probability of disengagement compared to other face stimuli.

It is important to note that on the bases of the previous and present results, the possible mechanisms behind our findings remain unclear. As the procedures have varied widely between studies (Kataja et al., 2018; Nakagawa & Sukigara, 2019b; Peltola et al., 2008), it is not possible to estimate how the levels of the fear bias in the two groups relate to normative levels of a fear bias in an infant population. Future studies are needed to further our understanding about the role that a lower fear bias plays among children with early RP.

Debate also continues about the implications of the very early RP for the later development of self-regulation. We found that early RP are related to a lower attention bias to fear at 8 months of age. As argued earlier, this may indicate either a delay or a difference in the development of the attention-orientation network, which is the most essential attention network supporting self-regulation during infancy (Posner et al., 2014). Our result is consistent with the suggestion of Todd et al. (2012) that affect-biased attention itself is a form of emotion regulation. Our results are also in line with those of Toffol et al. (2019), who showed that higher levels of behavioral RP at 1 month of age are associated with other important aspects of self-regulation, such as problem-solving skills and temperament. Furthermore, our results show that early RP at 3 months of age are related to the processing of emotional facial expressions, even when the effect of temperamental negative affectivity is controlled for, indicating that they play an independent role in predicting emotional attention at 8 months. Finally, our results support the view of Hemmi et al. (2011) being that all three aspects of RP—problems in feeding, sleeping, and crying—should be considered together because the results of the studies focusing only on excessive crying have been contradictory (Korja et al., 2014; Papoušek & Von Hofacker, 1998; Pauli-Pott et al., 2000).

The long-term implications of our findings remain to be explored. Several studies in adults have shown that different psychiatric symptom classifications may be variable concerning attention biases. There is evidence of an attention bias toward threat- or fear-related stimuli in many types of anxiety disorders (Bar-Haim et al., 2007; Cisler & Koster, 2010; Georgiou et al., 2005), toward sad faces in depression (Gotlib, Krasnoperova, Neubauer Yue, & Joormann, 2004), and toward food in eating disorders (Brooks, Prince, Stahl, Campbell, & Treasure, 2011). However, the developmental pathways are not yet fully understood. It has been stated that attention biases may maintain or enhance the effects of other developmental risk factors (Pérez-Edgar et al., 2010, 2011). In previous studies, the attention bias to threat was found to be the link between risk temperament, behavioral inhibition, and later social difficulties during childhood and adolescence (Pérez-Edgar et al., 2010, 2011). In a recent study, a "dot-probe task" for affect-biased attention used with adults and older children was modeled for infants and toddlers using eye tracking (Pérez-Edgar et al., 2017). The results showed an association between lower temperamental negative affectivity and lower attention bias to threat (Pérez-Edgar et al., 2017), which links the findings from infant studies with the findings from studies in older children combining affect-biased attention, temperamental risk-factors, and anxiety disorders (Pérez-Edgar et al., 2010, 2011). The CogBIAS theory of Fox and Beever (2016) examines about the role of cognitive bias, as attention bias, during development and claims that a cognitive bias in processing emotional information moderates the connection between genetic or environmental risk factors and well-being. The developmental outcomes of a lower attention bias to fearful faces at 8 months are an important topic for future research to interpret of the results of the present study.

Some limitations of the present study should be pointed out. First, we used the parents' subjective evaluation of their infant's RP. However, the reports of both parents were used to diminish the reporting bias. In future studies, more detailed questionnaires, interviews, or diaries of sleeping, eating, and crying could be used. Second, due to the longitudinal study design, the attrition rate was relatively high. Only 176 of the original 363 valid eye-tracking measurements could be used in our analysis due to missing questionnaire data. Third, the stimuli used in the eye-tracking procedure (i.e., the photos of faces and geometric shapes) were unnatural compared to an infant's environment. In future studies, the effect of the lower fear bias in emotion processing and real-life face-to-face interactions should be studied. Videos and more natural scenes could be used.

Conclusions

Our results suggest that behavioral RP at the age of 3 months, defined as problems in feeding, sleeping, and calming down, are associated with a lower attention bias to fearful faces at 8 months of age. This association remained significant after controlling for maternal depressive and anxiety symptoms and infant temperamental negative affectivity, which suggests an independent role for RP as a predictor of emotional attention during later infancy. This finding is in line with previous results showing an association between behavioral RP at the age of 1 month and other important aspects of self-regulation, such as problem-solving skills, negative affectivity temperament, and behavioral problems (Toffol et al., 2019). To our knowledge, this is the first study to show that very early infant regulatory behavior profiles are related to later emotionally directed attention disengagement patterns. The long-term implications of our results, presented here, on child development may be an important topic for future research.

References

Amso, D., Haas, S., & Markant, J. (2014). An eye tracking investigation of developmental change in bottom-up attention orienting to faces in cluttered natural scenes. *PLoS One*, *9*(1), 1–7. https://doi.org/10.1371/journal.pone.0085701

Aslin, R. N., & Salapatek, P. (1975). Saccadic localization of visual targets by the very young human infant. *Perception & Psychophysics*, *17*, 293–302. https://doi.org/10.3758/BF03203214

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin*, *133*(1), 1–24. https://doi.org/10.1037/0033-2909.133.1.1

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*. https://doi.org/10.18637/jss.v067.i01

Bertenthal, B. I., & Campos, J. J. (1984). A reexamination of fear and its determinants on the visual cliff. *Psychophysiology*, *21*, 413–417. https://doi.org/10.1111/j.1469-8986.1984.tb00218.x

Bowlby, J. (1969). *Attachment and loss. Volume 1. Attachment*, New York: Basic Books.

Bridgett, D. J., Burt, N. M., Edwards, E. S., & Deater-Deckard, K. (2015). Intergenerational transmission of self-regulation: A multidisciplinary review and integrative conceptual framework. *Psychological Bulletin*, *141*, 602–654. https://doi.org/10.1037/a0038662

Brooks, S., Prince, A., Stahl, D., Campbell, I. C., & Treasure, J. (2011). A systematic review and meta-analysis of cognitive bias to food stimuli in people with disordered eating behaviour. *Clinical Psychology Review*, *31* (1), 37–51. https://doi.org/10.1016/j.cpr.2010.09.006

Cisler, J. M., & Koster, E. H. W. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical Psychology Review*, *30*, 203–216. https://doi.org/10.1016/j.cpr.2009.11.003

Cox, J. L., Holden, J. M., & Sagovsky, R. (1987). Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. *British Journal of Psychiatry*, *150*, 782–786. https://doi.org/10.1007/978-94-007-1694-0_2

Crockenberg, S. C., & Leerkes, E. M. (2004). Infant and maternal behaviors regulate infant reactivity to novelty at 6 months. *Developmental Psychology*, *40*, 1123–1132. https://doi.org/10.1037/0012-1649.40.6.1123

de Barbaro, K., Clackson, K., & Wass, S. (2016). Stress reactivity speeds basic encoding processes in infants. *Developmental Psychobiology*, *58*, 546–555. https://doi.org/10.1002/dev.21399

Emde, R. N. (1998). Early emotional development: New modes of thinking for research and intervention. *Pediatrics*, *102*, 1236–1243.

Farroni, T., Menon, E., Rigato, S., & Johnson, M. H. (2007). The perception of facial expressions in newborns. *European Journal of Developmental Psychology*, *4*(1), 2–13. https://doi.org/10.1080/17405620601046832

Field, T. M. (1981). Infant gaze aversion and heart rate during face-to-face interactions. *Infant Behavior and Development*, *4*, 307–315. https://doi.org/10.1016/S0163-6383(81)80032-X

Forssman, L., Peltola, M. J., Yrttiaho, S., Puura, K., Mononen, N., Lehtimäki, T., & Leppänen, J. M. (2014). Regulatory variant of the TPH2 gene and early life stress are associated with heightened attention to social signals of fear in infants. *Journal of Child Psychology and Psychiatry*, *55*, 793–801. https://doi.org/10.1111/jcpp.12181

Fox, E., & Beevers, C. G. (2016). Differential sensitivity to the environment: Contribution of cognitive biases and genes to psychological wellbeing. *Molecular Psychiatry*, *21*, 1657–1662. https://doi.org/10.1038/mp.2016.114

Frank, M. C., Vul, E., & Johnson, S. P. (2009). Development of infants' attention to faces during the first year. *Cognition*, *110*, 160–170. https://doi.org/10.1016/j.cognition.2008.11.010

Frank, M. C., Vul, E., & Saxe, R. (2012). Measuring the development of social attention using free-viewing. *Infancy*, *17*, 355–375. https://doi.org/10.1111/j.1532-7078.2011.00086.x

Fu, X., & Pérez-Edgar, K. (2019). Threat-related attention bias in socioemotional development: A critical review and methodological considerations. *Developmental Review*, *51*, 31–57. https://doi.org/10.1016/j.dr.2018.11.002

Gartstein, M. A., & Rothbart, M. K. (2003). Studying infant temperament via the Revised Infant Behavior Questionnaire. *Infant Behavior and Development*, *26*(1), 64–86. https://doi.org/10.1016/S0163-6383(02)00169-8

Georgiou, G. A., Bleakley, C., Hayward, J., Russo, R., Dutton, K., Eltiti, S., & Fox, E. (2005). Focusing on fear: Attentional disengagement from emotional faces. *Visual Cognition*, *12*, 145–158. https://doi.org/10.1080/13506280444000076

Gotlib, I. H., Krasnoperova, E., Neubauer Yue, D., & Joormann, J. (2004). Attentional biases for negative interpersonal stimuli in clinical depression. *Journal of Abnormal Psychology*, *113*, 127–135. https://doi.org/10.1037/0021-843X.113.1.127

Gross, S. (2016). Approaches to diagnosing regulatory disorders. In M. Cierpka (Ed.), *Regulatory disorders in infants: Assessment, diagnosis, and treatment* (pp. 17–33). Cham, Switzerland: Springer.

Hart, H., Radua, J., Nakao, T., Mataix-Cols, D., & Rubia, K. (2013). Meta-analysis of functional magnetic resonance imaging studies of inhibition and attention in attention-deficit/hyperactivity disorder: Exploring task-specific, stimulant medication, and age effects. *JAMA Psychiatry*, *70*, 185–198. https://doi.org/10.1001/jamapsychiatry.2013.277

Hemmi, M. H., Wolke, D., & Schneider, S. (2011). Associations between problems with crying, sleeping and/or feeding in infancy and long-term behavioural outcomes in childhood: A meta-analysis. *Archives of Disease in Childhood*, *96*, 622–629. https://doi.org/10.1136/adc.2010.191312

Holi, M. M., Sammallahti, P. R., & Aalberg, V. A. (1998). A Finnish validation study of the SCL-90. *Acta Psychiatrica Scandinavica*, *97*(1), 42–46. https://doi.org/10.1111/j.1600-0447.1998.tb09961.x

Johnson, M. H., Posner, M. I., & Rothbart, M. K. (1991). Components of visual orienting in early infancy: Contingency learning, anticipatory looking, and disengaging. *Journal of Cognitive Neuroscience*, *3*, 335–344. https://doi.org/10.1162/jocn.1991.3.4.335

Johnson, M. H., Senju, A., & Tomalski, P. (2015). The two-process theory of face processing: Modifications based on two decades of data from infants and adults. *Neuroscience and Biobehavioral Reviews*, *50*, 169–179. https://doi.org/10.1016/j.neubiorev.2014.10.009

Jones, R., Slade, P., Pascalis, O., & Herbert, J. S. (2013). Infant interest in their mother's face is associated with maternal psychological health. *Infant Behavior and Development*, *36*, 686–693. https://doi.org/10.1016/j.infbeh.2013.07.002

Jusiene, R., Breidokiene, R., & Pakalniskiene, V. (2015). Developmental trajectories of mother reported regulatory problems from toddlerhood to preschool age. *Infant Behavior and Development*, *40*, 84–94. https://doi.org/10.1016/j.infbeh.2015.04.003

Karlsson, L., Tolvanen, M., Scheinin, N. M., Uusitupa, H., Korja, R., Ekholm, E., ... Huotilainen, M. (2018). Cohort profile: The FinnBrain Birth Cohort Study (FinnBrain). *International Journal of Epidemiology*, *47*(1), 15–16. https://doi.org/10.1093/ije/dyx173

Kataja, E.-L., Karlsson, L., Leppänen, J. M., Pelto, J., Häikiö, T., Nolvi, S., ... Karlsson, H. (2018). Maternal depressive symptoms during the pre- and postnatal periods and infant attention to emotional faces. *Child Development*, *91*. https://doi.org/10.1111/cdev.13152

Kataja, E.-L., Karlsson, L., Parsons, C. E., Pelto, J., Pesonen, H., Häikiö, T., ... Karlsson, H. (2019). Maternal pre- and postnatal anxiety symptoms and infant attention disengagement from emotional faces. *Journal of Affective Disorders*, *243*, 280–289. https://doi.org/10.1016/j.jad.2018.09.064

Kataja, E.-L., Leppänen, J. M., Kantojärvi, K., Pelto, J., Häikiö, T., Korja, R., ... Karlsson, L. (2020). Infant behavior and development the role of TPH2 variant rs4570625 in shaping infant attention to social signals. *Infant Behavior and Development*, *60*. https://doi.org/10.1016/j.infbeh.2020.101471

Kleberg, J. L., del Bianco, T., & Falck-Ytter, T. (2018). How infants arousal influences their visual search. *Child Development*. https://doi.org/10.1111/cdev.13198

Korja, R., Huhtala, M., Maunu, J., Rautava, P., Haataja, L., Lapinleimu, H., & Lehtonen, L. (2014). Preterm infant's early crying associated with child's behavioral problems and parents' stress. *Pediatrics*, *133*, 339–345. https://doi.org/10.1542/peds.2013-1204

LeDoux, J. (2012). Rethinking the emotional brain. *Neuron*, *73*, 653–676. https://doi.org/10.1016/j.neuron.2012.02.004

Leppänen, J. M., Cataldo, J. K., Enlow, M. B., & Nelson, C. A. (2018). Early development of attention to threat-related facial expressions. *PLoS One*, *13*, 1–13. https://doi.org/10.1371/journal.pone.0197424

Leppänen, J. M., Forssman, L., Kaatiala, J., Yrttiaho, S., & Wass, S. (2015). Widely applicable MATLAB routines for automated analysis of saccadic reaction times. *Behavior Research Methods*, *47*, 538–548. https://doi.org/10.3758/s13428-014-0473-z

Leppänen, J. M., & Nelson, C. A. (2009). Tuning the developing brain to social signals of emotions. *Nature Reviews Neuroscience*, *10*(1), 37–47. https://doi.org/10.1038/nrn2554

Leppänen, J. M., & Nelson, C. A. (2012). Early development of fear processing. *Current Directions in Psychological Science*, *21*, 200–204. https://doi.org/10.1177/0963721411435841

Leppänen, J. M., Peltola, M. J., Puura, K., Mäntymaa, M., Mononen, N., & Lehtimäki, T. (2011). Serotonin and early cognitive development: Variation in the tryptophan hydroxylase 2 gene is associated with visual attention in 7-month-old infants. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *52*, 1144–1152. https://doi.org/10.1111/j.1469-7610.2011.02391.x

Lewkowicz, D. J., & Turkewitz, G. (1981). Intersensory interaction in newborns: Modification of visual preferences following exposure to sound. *Child Development*, *52*, 827–832. https://doi.org/10.1111/j.1467-8624.1981.tb03120.x

Libertus, K., Landa, R. J., & Haworth, J. L. (2017). Development of attention to faces during the first 3 years: Influences of stimulus type. *Frontiers in Psychology*, *8*, 1–10. https://doi.org/10.3389/fpsyg.2017.01976

Marsh, A. A. (2016). Understanding amygdala responsiveness to fearful expressions through the lens of psychopathy and altruism. *Journal of Neuroscience Research*, *94*, 513–525. https://doi.org/10.1002/jnr.23668

Morales, S., Brown, K. M., Taber-Thomas, B. C., Lobue, V., Buss, K. A., & Pérez-Edgar, K. E. (2017). Maternal anxiety predicts attentional bias towards threat in infancy. *Emotion*, *17*, 874–883. https://doi.org/10.1037/emo0000275

Morales, S., Fu, X., & Pérez-Edgar, K. E. (2016). A developmental neuroscience perspective on affect-biased attention. *Developmental Cognitive Neuroscience*, *21*, 26–41. https://doi.org/10.1016/j.dcn.2016.08.001

Morales, S., Pérez-Edgar, K. E., & Buss, K. A. (2015). Attention biases towards and away from threat mark the relation between early dysregulated fear and the later emergence of social withdrawal. *Journal of Abnormal Child Psychology*, *43*, 1067–1078. https://doi.org/10.1007/s10802-014-9963-9

Nakagawa, A., & Sukigara, M. (2019a). Attentional bias assessed by a facial expression cuing paradigm in infants. *Scientific Reports*, *9*(1), 1–7. https://doi.org/10.1038/s41598-018-36806-1

Nakagawa, A., & Sukigara, M. (2019b). Early development of attentional disengagement and phasic alertness. *Infant Behavior and Development*, *55*, 38–45. https://doi.org/10.1016/j.infbeh.2019.02.004

Nordahl, C. W., & Schumann, C. M. (2019). Early variations in amygdala development may signal divergent behavioral outcomes. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *4*(1), 3–4. https://doi.org/10.1016/j.bpsc.2018.11.009

Öhman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review*, *108*, 483–522. https://doi.org/10.1037/0033-295X.108.3.483

Papoušek, M., & Von Hofacker, N. (1998). Persistent crying in early infancy: A non-trivial condition of risk for the developing mother-infant relationship. *Child: Care, Health and Development*, *24*, 395–424. https://doi.org/10.1046/j.1365-2214.2002.00091.x

Pauli-Pott, U., Becker, K., Mertesacker, T., & Beckmann, D. (2000). Infants with "Colic"—Mothers' perspectives on the crying problem. *Journal of Psychosomatic Research*, *48*, 125–132. https://doi.org/10.1016/S0022-3999(99)00084-7

Peltola, M. J., Leppänen, J. M., Mäki, S., & Hietanen, J. K. (2009). Emergence of enhanced attention to fearful faces between 5 and 7 months of age. *Social Cognitive and Affective Neuroscience*, *4*, 134–142. https://doi.org/10.1093/scan/nsn046

Peltola, M. J., Leppänen, J. M., Palokangas, T., & Hietanen, J. K. (2008). Fearful faces modulate looking duration and attention disengagement in 7-month-old infants. *Developmental Science*, *11*(1), 60–68. https://doi.org/10.1111/j.1467-7687.2007.00659.x

Peltola, M. J., Yrttiaho, S., & Leppänen, J. M. (2018). Infants' attention bias to faces as an early marker of social development. *Developmental Science*, *21*, 1–14. https://doi.org/10.1111/desc.12687

Pérez-Edgar, K., Bar-Haim, Y., Martin McDermott, J., Chronis-Tuscano, A., Pine, D. S., & Fox, N. A. (2010). Attention biases to threat and behavioral inhibition in early childhood shape adolescent social withdrawal. *Emotion*, *10*, 349–357. https://doi.org/10.1037/a0018486

Pérez-Edgar, K., Morales, S., LoBue, V., Taber-Thomas, B. C., Allen, E. K., Brown, K. M., & Buss, K. A. (2017). The impact of negative affect on attention patterns to threat across the first 2 years of life. *Developmental Psychology*, *53*, 2219–2232. https://doi.org/10.1037/dev0000408

Pérez-Edgar, K., Reeb-Sutherland, B. C., Martin McDermott, J., White, L. K., Henderson, H. A., Degnan, K. A., . . . Fox, N. A. (2011). Attention biases to threat link behavioral inhibition to social withdrawal over time in very young children. *Journal of Abnormal Child Psychology*, *39*, 885–895. https://doi.org/10.1007/s10802-011-9495-5

Pessoa, L., & Adolphs, R. (2010). Emotion processing and the amygdala: From a "low road" to "many roads" of evaluating biological significance. *Nature Reviews Neuroscience*, *11*, 773–782. https://doi.org/10.1038/nrn2920

Posner, M. I., Rothbart, M. K., Sheese, B. E., & Voelker, P. (2014). Developing attention: Behavioral and brain mechanisms. *Advances in Neuroscience*, *2014*, 405094. https://doi.org/10.1155/2014/405094

Pourtois, G., Grandjean, D., Sander, D., & Vuilleumier, P. (2004). Electrophysiological correlates of rapid spatial orienting towards fearful faces. *Cerebral Cortex*, *14*, 619–633. https://doi.org/10.1093/cercor/bhh023

R Core Team (2018). *A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. Available online at https://www.R-project.org/.

Rothbart, M. K., & Derryberry, D. (1981). Development of individual differences in temperament. In M. E. Lamb & A. L. Brown (Eds.), *Advances in Developmental Psychology* (Vol. *1*). Hillsdale, NJ: Erlbaum.

Rothbart, M. K., Sheese, B. E., Rueda, M. R., & Posner, M. I. (2011). Developing mechanisms of self-regulation in early life. *Emotion Review*, *3*, 207–213. https://doi.org/10.1177/1754073910387943

Salzwedel, A. P., Stephens, R. L., Goldman, B. D., Lin, W., Gilmore, J. H., & Gao, W. (2019). Development of amygdala functional connectivity during infancy and its relationship with 4-year behavioral outcomes. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *4*(1), 62–71. https://doi.org/10.1016/j.bpsc.2018.08.010

Santos, I. S., Matijasevich, A., Capilheira, M. F., Anselmi, L., & Barros, F. C. (2015). Excessive crying at 3 months of age and behavioural problems at 4 years age: A prospective cohort study. *Journal of Epidemiology and Community Health*, *69*, 654–659. https://doi.org/10.1136/jech-2014-204568

Schmid, G., Schreier, A., Meyer, R., & Wolke, D. (2010). A prospective study on the persistence of infant crying, sleeping and feeding problems and preschool behaviour. *Acta Paediatrica*, *99*, 286–290. https://doi.org/10.1111/j.1651-2227.2009.01572.x

Schmid, G., Schreier, A., Meyer, R., & Wolke, D. (2011). Predictors of crying, feeding and sleeping problems: A prospective study. *Child: Care, Health and Development*, *37*, 493–502. https://doi.org/10.1111/j.1365-2214.2010.01201.x

Schmid, G., & Wolke, D. (2014). Preschool regulatory problems and attention-deficit/hyperactivity and cognitive deficits at school age in children born at risk: Different phenotypes of dysregulation? *Early Human Development*, *90*, 399–405. https://doi.org/10.1016/j.earlhumdev.2014.05.001

Shechner, T., Britton, J. C., Pérez-Edgar, K., Bar-Haim, Y., Ernst, M., Fox, N. A., ... Pine, D. S. (2012). Attention biases, anxiety, and development: Toward or away from threats or rewards? *Depression and Anxiety*, *29*, 282–294. https://doi.org/10.1002/da.20914

Smarius, L. J. C. A., Strieder, T. G. A., Loomans, E. M., Doreleijers, T. A. H., Vrijkotte, T. G. M., Gemke, R. J., & van Eijsden, M. (2017). Excessive infant crying doubles the risk of mood and behavioral problems at age 5: Evidence for mediation by maternal characteristics. *European Child & Adolescent Psychiatry*, *26*, 293–302. https://doi.org/10.1007/s00787-016-0888-4

Thiel-Bonney, C., & Cierpka, M. (2016). Excessive crying. In M. Cierpka *Regulatory disorders in infants: Assessment, Diagnosis, and Treatment*, Cham: Springer.

Todd, R. M., Cunningham, W. A., Anderson, A. K., & Thompson, E. (2012). Affect-biased attention as emotion regulation. *Trends in Cognitive Sciences*, *16*, 365–372. https://doi.org/10.1016/j.tics.2012.06.003

Toffol, E., Rantalainen, V., Lahti-Pulkkinen, M., Girchenko, P., Lahti, J., Tuovinen, S., ... Räikkönen, K. (2019). Infant regulatory behavior problems during first month of life and neurobehavioral outcomes in early childhood. *European Child and Adolescent Psychiatry*, *28*, 847–859. https://doi.org/10.1007/s00787-018-1243-8

Tuulari, J. J., Kataja, E.-L., Leppänen, J. M., Lewis, J. D., Nolvi, S., Häikiö, T., ... Karlsson, H. (2020). Newborn left amygdala volume associates with attention disengagement from fearful faces at eight months. *Developmental Cognitive Neuroscience*, *45*. https://doi.org/10.1016/j.dcn.2020.100839

Whalen, P. J. (1998). Fear, vigilance, and ambiguity: Initial neuroimaging studies of the human amygdala. *Current Directions in Psychological Science*, *7*, 177–188. https://doi.org/10.1111/1467-8721.ep10836912

Wickham, H. (2009). *ggplot2: Elegant graphics for data analysis*. New York, NY: Springer-Verlag.

Woody, M. L., James, K., Foster, C. E., Owens, M., Feurer, C., Kudinova, A. Y., & Gibb, B. E. (2019). Children's sustained attention to emotional facial expressions and their autonomic nervous system reactivity during parent–child interactions. *Biological Psychology*, *142*, 37–44. https://doi.org/10.1016/j.biopsycho.2019.01.005

Yrttiaho, S., Forssman, L., Kaatiala, J., & Leppänen, J. M. (2014). Developmental precursors of social brain networks: the emergence of attentional and cortical sensitivity to facial expressions in 5 to 7 months old infants. *PLoS One*, *9*, e100811. https://doi.org/10.1371/journal.pone.0100811

Zero to Three (2016). *DC: 0-5: Diagnostic classification of mental health and developmental disorders of infancy and early childhood*, Washington, DC: Zero to Three.