TURUN YLIOPISTO
UNIVERSITY OF TURKU

AFFECT-BIASED ATTENTION AND SOCIAL-EMOTIONAL FUNCTIONING DURING EARLY CHILDHOOD

The FinnBrain Birth Cohort Study

Eeva Eskola

TURUN YLIOPISTON JULKAISUJA – ANNALES UNIVERSITATIS TURKUENSIS
SARJA – SER. B OSA – TOM. 664 | HUMANIORA | TURKU 2024

TURUN YLIOPISTO
UNIVERSITY OF TURKU

AFFECT-BIASED ATTENTION AND SOCIAL-EMOTIONAL FUNCTIONING DURING EARLY CHILDHOOD

The FinnBrain Birth Cohort Study

Eeva Eskola

TURUN YLIOPISTON JULKAISUJA – ANNALES UNIVERSITATIS TURKUENSIS
SARJA – SER. B OSA – TOM. 664 | HUMANIORA | TURKU 2024

University of Turku

Faculty of Social Sciences
Department of Psychology and Speech-Language Pathology
Psychology
Doctoral Programme of Social and Behavioral Sciences

Supervised by

Professor, Riikka Korja
Department of Psychology and Speech-Language Pathology
University of Turku, Finland

Professor, Jukka Hyönä
Department of Psychology and Speech-Language Pathology
University of Turku, Finland

Reviewed by

Senior Assistant Professor, Evin Aktar
Department of Clinical Psychology
Leiden University, The Netherlands

Head of Research, Jarkko Hautala
Niilo Mäki Institute
Jyväskylä, Finland

Opponent

Senior Assistant Professor Evin Aktar
Department of Clinical Psychology
Leiden University, The Netherlands

The originality of this Publication has been checked in accordance with the University of Turku quality assurance system using the Turnitin OriginalityCheck service.

Cover Image: Oiva Ristimäki

ISBN 978-951-29-9678-0 (PRINT)
ISBN 978-951-29-9679-7 (PDF)
ISSN 0082-6987 (Print)
ISSN 2343-3191 (Online)
Painosalama, Turku, Finland 2024

To my parents and grandparents

UNIVERSITY OF TURKU
Faculty of Social Sciences
Department of Psychology and Speech-Language Pathology
Psychology
EEVA ESKOLA: Affect-Biased Attention and Social-Emotional Functioning during Early Childhood. The FinnBrain Birth Cohort Study.
Doctoral Dissertation, 199 pp.
Doctoral Programme of Social and Behavioral Sciences
March 2024

ABSTRACT

Affect-biased attention is defined as perceptual preference for an object based on its affective saliency. Affect-biased attention has been suggested to have reciprocal connections with other aspects of social-emotional functioning. However, it is not yet known how these connections manifest and develop during infancy and toddlerhood.

The aims of this study were to investigate the associations between affect-biased attention at 8 months and the four aspects of social-emotional functioning being: 1) early behavioral regulatory problems at 3 months (Study I), 2) social-emotional problems and 3) social-emotional competencies at 2 years (Study II) as well as 4) the quality of maternal caregiving behaviors at 8 months (Study III). In addition, to further understand normative development, the change in affect-biased attention was studied between 2.5 and 5 years (Study IV). The sample of this longitudinal study was comprised of children and their parents from the FinnBrain Birth Cohort Study.

The main findings were that an increased attention bias toward fear at 8 months was associated with less regulatory problems at 3 months and higher socioemotional competencies at 2 years. In addition, a lower quality of maternal caregiving behaviors was related to increased attention toward fear. The substudy on developmental changes occurring between 2.5 and 5 years showed increased attention biases in sustained attention for happy, fearful, angry and sad faces compared to a neutral face.

The results suggest that attention biases for fear and threat may play a different role in well-being during the early years compared to connections observed later in life. In the present study, an increased attention bias toward fear at 8 months was also related to positive aspects of early development. In addition, all studied attention biases, including attention bias toward fear and anger, increased during typical development between 2.5 and 5 years. However, the associations seem to be complex, as increased attention toward fear was also related to a lower quality of maternal caregiving behaviors.

KEYWORDS: affect-biased attention, fear bias, face bias, behavioral regulatory problems, socioemotional problems, socioemotional competencies, caregiving behaviors, emotional availability, mother–infant interaction, infants, toddlers, early development, eye tracking

TURUN YLIOPISTO
Yhteiskuntatieteellinen tiedekunta
Psykologian ja logopedian laitos
Psykologia
EEVA ESKOLA: Tunneohjautunut tarkkaavuus ja sosioemotionaaliset toiminnot varhaislapsuuden aikana
Väitöskirja, 199 s.
Yhteiskunta- ja käyttäytymistieteiden tohtoriohjelma
Maaliskuu 2024

TIIVISTELMÄ

Tunneohjautunut tarkkaavuus tarkoittaa määritelmän mukaan sitä, että havaittavaa kohdetta suositaan sen tunteisiin liittyvän sisällön vuoksi. Viimeisimmät teoriat esittävät, että tunneohjautuneella tarkkaavuudella on vastavuoroinen vuorovaikutussuhde muun sosioemotionaalisen toiminnan kanssa. Vielä ei kuitenkaan tiedetä, miten nämä yhteydet kehittyvät varhaislapsuudessa.

Tämän tutkimuksen tavoitteena oli tutkia pelokkaisiin kasvoihin liittyvän tarkkaavuuden vinouman yhteyttä neljään sosioemotionaaliseen tekijään 1) varhaisiin säätelyongelmiin 3 kuukauden iässä (Tutkimus I), 2) sosioemotionaalisiin ongelmiin ja 3) taitoihin 2 vuoden iässä (Tutkimus II) ja 4) äidin vanhemmuuden laatuun (Tutkimus III). Lisäksi tutkittiin tunneohjautuneen tarkkaavuuden tavanomaista kehitystä 2,5 ja 5 vuoden välillä (Tutkimus IV). Tutkittavat lapset ja heidän vanhempansa kuuluvat FinnBrain-tutkimukseen, joka on pitkittäistutkimus.

Tutkimuksen päätulosten mukaan lapsilla, joilla oli 8 kuukauden iässä voimakkaampi tarkkaavuuden vinouma pelokkaita kasvoja kohti, oli ollut 3 kuukauden iässä vähemmän säätelyongelmia ja heillä oli paremmat sosioemotionaaliset taidot 2-vuotiaana. Äidin vanhemmuuden heikompi laatu oli yhteydessä tarkkaavuuden voimakkaampaan vinoumaan kohti pelokkaita kasvoja. Lisäksi todettiin, että tarkkaavuuden ylläpitoon liittyvät vinoumat kohti iloisia, pelokkaita, vihaisia ja surullisia kasvoja voimistuvat 2,5 ja 5 ikävuoden välillä.

Tämän tutkimuksen tulokset viittaavat siihen, että pelkoon ja uhkaan liittyvillä tarkkaavuuden vinoumilla on erilainen merkitys hyvinvoinnille ensimmäisten elinvuosien aikana verrattuna myöhempiin vuosiin. Tässä tutkimuksessa pelkoon liittyvä tarkkaavuuden vinouma oli yhteydessä myös myönteisiin kehityksen piirteisiin. Lisäksi kaikki tutkitut tarkkaavuuden vinoumat mukaan lukien vinoumat pelokkaita ja vihaisia kasvoja kohti voimistuivat tyypillisessä kehityksessä 2,5 ja 5 ikävuoden välillä. Yhteydet vaikuttavat kuitenkin olevan monimutkaisia, sillä voimakkaampi tarkkaavuuden vinouma kohti pelokkaita kasvoja oli yhteydessä myös äidin vanhemmuuden heikompaan laatuun.

ASIASANAT: tunneohjautunut tarkkaavuus, pelkovinouma, kasvovinouma, varhaiset säätelyongelmat, sosioemotionaaliset ongelmat, sosioemotionaaliset taidot, hoivakäyttäytyminen, emotionaalinen saatavillaolo, äidin ja lapsen välinen vuorovaikutus, vauva, taapero, varhainen kehitys, katseenseuranta

Acknowledgements

First, I want to express my gratitude to my wise and the most warm-hearted supervisors, professors Riikka Korja and Jukka Hyönä. Riikka, I admire your ability to combine scientific and clinical ambitions and to focus on the most important topics regarding current scientific discussions and needs in our society. Jukka, you taught me clear scientific thinking and precise reporting. I admire your endless efforts in improving the language of our manuscripts.

I want to thank my esteemed opponent senior assistant professor Evin Aktar. I'm privileged to have such an expert in the public defense of my dissertation. Thank you for sharing your expertise and most accurate comments during the pre-examination of my thesis. I want to thank the other pre-examiner, adjunct professor Jarkko Hautala for the valuable comments that improved this thesis.

I want to express my gratitude to professors Linnea Karlsson and Hasse Karlsson for this great opportunity to be part of FinnBrain family. I usually say I applied to your project because it has the best parties. However, the real reason was your goal to find solutions to mental health crisis that we are encountering in our society. I'm eager to see not only the results of FinnBrain Study but also the societal impact to which your dream will lead.

I want to thank my co-authors and those who have made essential work for the original papers of this thesis. Thank you, adjunct professors Eeva-Leena Kataja and Saara Nolvi, for creating 8-month study visits. Eeva-Leena, your vision of FinnBrain eye-tracking studies inspired me and made this study possible. Both of you, thank you for your friendship and support. Thank you, PhD Tuomo Häikiö, for sharing your expertise in eye-tracking methodology. Thank you, statistician Juho Pelto: your enthusiasm for understanding the data catches us others, too. Thank you, assosiate professor Jetro Tuulari and professor Jukka Leppänen for your help with the eye-tracking data. Thank you, Eija Sinervä, for organizing the mother–infant interaction observation in the study visit at 8 months. I want to thank Robert M. Badeau, who performed the English language checking for all original papers and the thesis summary.

I feel privileged to study my research questions using this large, longitudinal dataset. My deepest gratitude goes to the participating FinnBrain families. Your active and dedicated participation has made this research possible. I also want to thank all research assistants who have collected the data and have taken care of our precious participants during the study visits. Thank you, project coordinator Eija Jossandt: you are always ready to help. Thank you, data manager Teemu Kemppainen: your sense of humor helped me to go through the most pedantic phases of cleaning the data. Thank you, research coordinator Susanne Sinisalo: you are my role model when it comes to selfless caring of other people. Thank you, PhD Susanna Kortesluoma: everybody feels welcomed, when you are at the office.

I want to thank the funders of FinnBrain Study: Finnish State Grants for Clinical Research (ERVA), Jane and Aatos Erkko Foundation, Jenny and Antti Wihuri Foundation, the Finnish Cultural Foundation and Academy of Finland among many others. I also want to thank Signe and Ane Gyllenberg Foundation, Maire Taposen säätiö and the Turku Univesity Foundation for their grants.

I've been privileged to share the PhD studies with the most talented and fun fellow students. Thank you, my research sisters PhD Elisabeth Nordenswan, PhD Eeva Holmberg and PhD Candidate Hetti Lahtela. Thank you for sharing good and bad days. As part of my PhD studies, I specialized in neuropsychology. Thank you, my dear colleagues Annika Koivisto, Emilia Häyry and Nelli Rainio for every professional and non-professional discussion. I want to thank MD Paula Mustonen, who has shared this early career stage both in scientific and clinical work. I want to thank the members of the peer supporting group Apple Thieves Collective, Joonas and Erik, the masters of bizarre discussions. Thank you, amazing researches from Tutkijaretriitti: I really appreciate all discussions and prayers that we shared.

I want to thank psychologist Anna Nieminen and PhD Candidate Anniina Karonen for sharing the joys of data collection with toddlers. I also want to thank other colleagues and talented members of Psykotiimi of FinnBrain. During the last year, I have had an opportunity to improve my skills as a researcher in the Centre of Excellence for Learning Dynamics and Intervention Research. My special thanks go to our PI, professor Paavo Leppänen. Thank you, PhD Katja Tervahartiala and PhD Fiia Takio, incredible members of InterLearn Turku team.

I also want to thank my clinical mentors. Thank you, neuropsychologist Jutta Torsti: you have somehow helped me with every move I've made in my career. Thank you adjunct professor Tapio Korhonen, PhD Anna Nyman, PhD Hanna Kiiski-Mäki and speech therapist Ulla Ström for guiding me in my clinical work with scientific perspective as part of your holistic supervision.

This work has never been finished without study leaves from my clinical work. I want to thank neuropsychologist Marja-Kaisu Norvasuo-Heilä and adjunct professor Tuire Lähdesmäki for supporting this project. Thank you, great clinicians Nea, Maija, Hanna, Emma and Maria for supporting me through these years and supervising new psychologists when I was at the university. I want to thank all talented psychologists who covered my job while I was doing research.

I want to thank my other friends for your love and support. Thank you "Martin tytöt" and the spouses: Venla and Oskari, Katri and Joona-Pekko. Thank you Jenni and Juho for sharing the support bubble during the pandemic. Thank you Elina, Miika, Maria, Anna, Juhana, Sari, Tommi, Liisa, Hanna, Ilmari, Elina, Pekka, Karoliina and Berndt. Thank you Antti-Kalle, my favorite peripheral distractor.

I want to thank my sister Elisa and my brother-in-law Oiva together with your lovely children Aapo, Saima and Kaius. Your support has been invaluable. Thank you also distracting me from my work every now and then. Thank you, my parents Tiina and Timo Eskola and my beloved grandmother Raija Eskola. You have raised me to ask questions and to seek knowledge. It has put the most interesting adventures on my way. You together with my other grandparents have always supported me in my career and never questioned my possibilities. I dedicate this thesis to you.

... perfect love expels all fear. (1. John. 4:18)

Turku, 25.3.2024
Eeva Eskola

Table of Contents

Tables

Figures

List of Original Publications

This thesis is based on the following original publications, which are referred as Studies I–IV in the text.

I Eskola, E., Kataja, E.-L., Hyönä, J., Häikiö, T., Pelto, J., Karlsson, H., Karlsson, L., & Korja, R. (2021). Behavioral regulatory problems are associated with a lower attentional bias to fearful faces during infancy. *Child Development, 92(4),* 1539–1553. https://doi.org/10.1111/cdev.13516

II Eskola, E., Kataja, E.-L., Hyönä, J., Nolvi, S., Häikiö, T., Carter, A. S., Karlsson, H., Karlsson L., Korja, R. (2023). Higher attention bias for fear at 8 months of age is associated with better socioemotional competencies during toddlerhood. *Infant Behavior and Development, 71,* https://doi.org/10.1016/j.infbeh.2023.101838

III Eskola, E., Kataja, E.-L., Hyönä, J., Hakanen, H., Nolvi, S., Häikiö, T., Pelto, J., Karlsson, H., Karlsson, L., & Korja, R. (2024). Lower maternal emotional availability is related to increased attention toward fearful faces during infancy. *Infant Behavior and Development, 74,* https://doi.org/10.1016/j.infbeh.2023.101900

IV Eskola, E., Kataja, E.-L., Pelto, J., Tuulari, J. J., Hyönä, J., Häikiö, T., Hessels, R. S., Holmberg, E., Nordenswan, E., Karlsson, H., Karlsson, L., & Korja, R. (2023). Attention biases for emotional facial expressions during a free viewing task increase between 2.5 and 5 years of age. *Developmental Psychology, 59 (11),* 2065–2079. https://doi.org/10.1037/dev0001598

1 Introduction

Facial expressions of emotion are important sources of social and emotional information about the environment from early on. Attentional processes determine the selection of the information for other cognitive processes, such as perception, learning and memory (Amso & Scerif, 2015). Attention to faces provides a foundation for social interaction, and later, for social-emotional development (Klin et al., 2015; Morales, Fu, et al., 2016; Reynolds & Roth, 2018). Infants show an attention bias for faces and emotional expressions of emotion right after birth (Farroni et al., 2007; Johnson et al., 2015). Selective attention processes that prioritize perception of salient affective stimuli have been defined as *affect-biased attention* (Todd et al., 2012). Affect-biased attention is explained by its biological relevance, as due to limited information processing capacity, perceptual systems need to select the information most relevant for survival and other goals (Öhman & Mineka, 2001; Pessoa & Adolphs, 2010).

Theoretical models have assumed that affect-biased attention is one of the first forms of self-regulation (Rothbart et al., 2011; Todd et al., 2012), and it has reciprocal connections to social-emotional functioning (Morales, Fu, et al., 2016). Infants' processing of emotional facial expressions has been widely studied during the past 15 years (Fu & Pérez-Edgar, 2019; Morales, Fu, et al., 2016) at least partly due to the rapid development of eye-tracking measurements that has made the investigation of gaze behavior easier and more precise. During that time, an infant's specific attention bias for fearful faces, which was found already by Nelson and Dolkin in 1985, has been confirmed in many studies (Kataja, Karlsson, et al., 2020; Peltola et al., 2008; Pyykkö et al., 2018). However, the association between individual variance in attention bias for fearful faces during infancy and social-emotional functioning remains understudied.

Behavioral regulatory problems, a child's temperament and the parent–child interaction form a basis for social-emotional well-being (Biringen et al., 2014; Bridgett et al., 2015; Hemmi et al., 2011; Rothbart et al., 2011). From toddlerhood on, socioemotional problems together with socioemotional competencies describe a child's social-emotional well-being (Briggs-Gowan et al., 2004; Briggs-Gowan et al., 2016). During infancy, behavioral regulatory problems are defined as problems in sleeping and feeding and excessive crying. During toddlerhood, children's social-emotional problems include internalizing and externalizing symptoms as well as behavioral regulatory problems (Briggs-Gowan et al., 2016). However, neither behavioral regulatory problems during infancy nor social-emotional problems during toddlerhood have been studied in relation to the development of affect-biased attention.

In addition to social-emotional problems, social-emotional competencies are an important aspect of toddlers' socioemotional functioning and well-being. Socio-emotional competencies comprise behaviors indicating that the child has achieved age-appropriate, social-emotional development, such as cooperating with others and social participation (Briggs-Gowan & Carter, 1998; Feldman & Masalha, 2010). Previous studies suggest associations between a general attention bias for faces or an attention bias specifically for fearful faces during infancy and social behaviors during toddlerhood and the preschool years (Bedford et al., 2015; Peltola et al., 2018; Rajhans et al., 2016). However, these studies have focused on social behaviors, and there is a lack of studies on affect-biased attention and social-emotional competencies more broadly.

In addition to these internal factors, i.e., behavioral regulatory problems and social-emotional problems and competencies, factors in the infants' environment may be related to the development of affect-biased attention (Morales, Fu, et al., 2016). The quality of parenting behaviors is a key factor in an infant's environment, but the studies on its associations with an infant's affect-biased attention are scarce. Some previous studies have shown an association between affect-biased attention during infancy and childhood and other family-related factors, such as maternal anxiety and depressive symptoms (Fu & Pérez-Edgar, 2019; Kataja, Karlsson, et al., 2020; Kataja et al., 2019; Morales, Brown, et al., 2017; Otte et al., 2015) and adverse childhood family experiences (Gibb et al., 2011; Gulley et al., 2014; Lindblom et al., 2017; Loman & Gunnar, 2010; Pollak, 2015; Pollak & Kistler, 2002; Pollak & Sinha, 2002; Teicher & Samson, 2016; Tottenham et al., 2010).

The present study is a part of FinnBrain Birth Cohort Study. The aim of the study is to investigate to what extent affect-biased attention during infancy, more precisely at 8 months of age, is related to other aspects of social-emotional functioning during early childhood specifically behavioral regulatory problems, social-emotional problems and competencies and the quality of parenting behaviors (Figure 1). Another aim is to study the normative development of affect-biased attention from toddlerhood to the preschool years. The Table of Content provides information especially to those researchers and experts, who are familiar with the key concepts. For those readers to whom the topic is new, the key concepts are introduced in the next chapter.

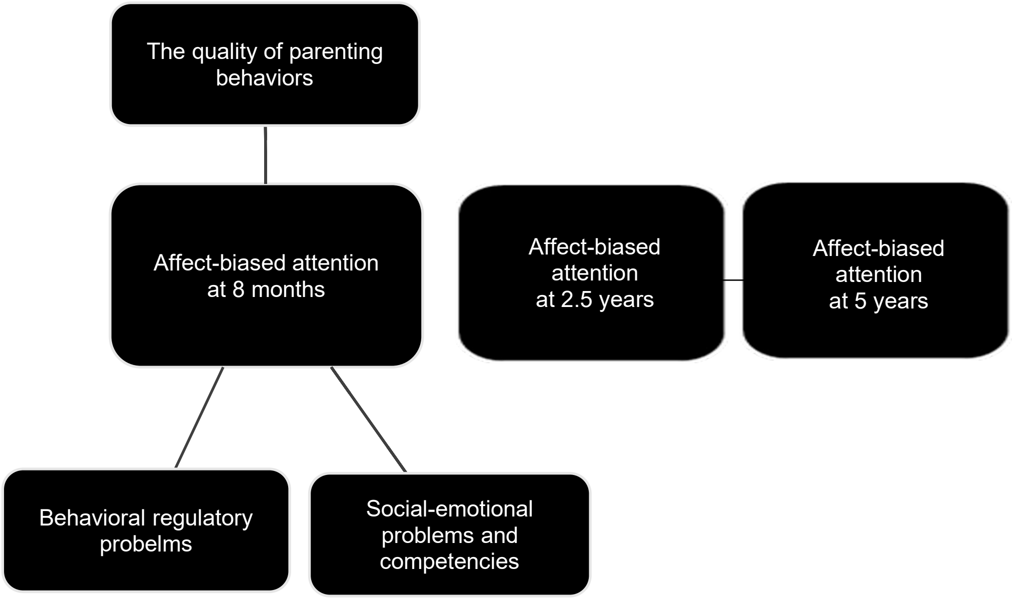

Figure 1. The main associations between affect-biased attention and social-emotional functioning studied in this thesis.

2 Review of the Literature

2.1 Attention Biases for Emotional Facial Expressions

2.1.1 Perception and Visual Attention to Faces During Early Childhood

Faces and facial expressions are important sources of social and emotional information about the environment from early on and provide a foundation for social interaction (Senju & Johnson, 2009). Humans have a sensitivity for faces right after birth, i.e., already at the time when their visual systems are immature and attention control capacities are limited (Johnson et al., 2015; Posner et al., 2014; Reynolds & Roth, 2018). Interestingly, a preference for face-like patterns has been found even in fetuses during the third trimester of pregnancy (Reid et al., 2017), and when the face stimuli were presented subliminally to 3-month-old infants (Nava et al., 2016). The findings describing the changes in an attention bias for faces over the course of development remain unsettled (Amso et al., 2014; Frank et al., 2009, 2012; Libertus et al., 2017). In studies including static stimuli or static and dynamic stimuli, children demonstrated a clear attention bias for faces during their first year after birth, but the bias for faces declined during the second year (Kataja et al., 2022; Libertus et al., 2017). However, in longitudinal studies using complex social scenes, children looked more at faces than at the other parts of the body or at the context of the scene, and this phenomenon grows throughout early development (Amso et al., 2014; Frank et al., 2009). Thus, previous findings indicate a clear attention bias for faces during childhood.

Previous studies have shown that infants can process also facial expressions of emotion early on. Neonates have been shown to be able to make a distinction between emotional facial expressions, as they have imitated a model's happy, sad and surprised facial expressions (Field, 1981). Three-month-old infants have shown the ability to discriminate between the positive and negative valence of facial expressions, for example, happy and sad, in task paradigms that observe infants' reactions to novelty (Young-Browne et al., 1977). The ability to discriminate between different negative emotional expressions, such as fear, anger and sadness, emerges by 5 months of age (Schwartz et al., 1985). During early childhood, children start to show an adult-like categorical perception of emotional facial expressions, which means that reactions to facial expressions of the same emotion with small variation are similar and differ from reactions to facial expressions of a different emotion (Kotsoni et al., 2001). In other words, emotional facial expressions are perceived as distinctive emotional categories rather than different points in a continuum (Kotsoni et al., 2001). Categorical perception of a fearful facial expression emerges by 7 months of age (Kotsoni et al., 2001), an angry facial expression by 9 months of age (Lee et al., 2015) and a sad facial expression by 26 months of age (Lee et al., 2020) when compared with happy faces. In conclusion, newborn babies have some innate sensitivity to emotional facial expressions, and the finely tuned and adult-like processing develops rapidly during infancy.

2.1.2 Affect-Biased Attention

Affect-biased attention can be defined as a perceptual preference for an object based on its affective salience (Todd et al., 2012). It refers to the pre-tuning of sensory systems so that certain affectively salient stimuli are perceived over others (Todd et al., 2012). Although affect-biased attention has been seen as a reactive, “bottom-up” process, more recently, it is considered as a “top-down” process, as it proactively shapes the perceptual experience (Todd et al., 2012). Attentional processes impose a bottleneck for information processing, as they determine the selection of information for the subsequent cognitive processes, such as perception, action, learning and memory (Amso & Scerif, 2015). Adopting the idea of affect-biased attention as a filtering process that actively shapes the information extracted from the environment, affect-biased attention has been considered as a form of emotion regulation (Todd et al., 2012). Human information processing capacity is limited; thus, perceptual systems need to select the information most relevant to survival and other goals (Öhman & Mineka, 2001; Pessoa & Adolphs, 2010). Therefore, affect-biased attention, as other attention biases, can be explained by their biological relevance.

Emotional attention biases are manifested in different subcomponents of attention (Amso & Scerif, 2015; Cisler & Koster, 2010; Morales, Fu, et al., 2016; Yiend, 2010). Cisler and Koster (2010) describe three interrelated aspects of attention biases: (1) observed, behavioral components, (2) mechanisms that mediate the expression of these components and (3) the information processing stage. All these aspects provide ways to divide attention processes into specific subcomponents, and attention biases can be seen in each subcomponent. First, regarding behavioral components, attention processes can be divided into facilitated attention to a target with difficulty in disengagement and attentional avoidance

(Cisler & Koster, 2010). Second, regarding mechanisms mediating expressions of the behavioral components, attention processes have been divided into three subcomponents based on underlying neural networks: the alerting network, the orienting network and executive attention (Posner et al., 2014). Newborn infants have a capacity for simple visual alerting, whereas their capacity for attention-orienting mechanisms including, to some extent, controlled attention shifts are manifested between 4–6 months of age (Amso & Scerif, 2015; Posner et al., 2014). Attention orienting includes disengaging, shifting and engaging (Posner et al., 1984; Yiend, 2010). The development of executive attention is linked to attention-orienting mechanisms, and its development continues until adolescence or young adulthood (Amso & Scerif, 2015; Posner et al., 2014). Third, regarding the information processing stage, attention processes can be divided into automatic and strategic information processing (Cisler & Koster, 2010). Facilitated attention towards a target is an automatic process (Cisler & Koster, 2010). Automaticity includes features such as speed, minimal resource requirements, a process below the threshold of conscious awareness and being resistant to intentional control (Yiend, 2010). Attention biases are seen also when the conscious perception of the emotional targets is prevented, that is, subliminally (Bar-Haim et al., 2007; Yiend, 2010). Strategic data processing is more involved in attentional disengagement and even more in attentional avoidance (Cisler & Koster, 2010).

In addition to the model of Cisler and Koster (2010), other divisions of attention processes can be found in the literature. In terms of temporal dimension, effects of attention bias range from initial alerting to a sustained attention to the target (Amso & Scerif, 2015). Finally, attention can also be divided into exogenous and endogenous attention (Wass, 2018). Exogenous attention means externally driven attention when an object in the environment captures an individual’s attention. Endogenous, voluntary attention control, i.e., internally driven attention, is thought to mature during childhood, and it is hard to measure during infancy (Posner et al., 2014; Wass, 2018). All these divisions can be applied when measuring affect-biased attention.

2.1.3 Measuring of Affect-Biased Attention

Several tasks can study emotional attention biases in different components of attention in laboratory settings using behavioral reaction time measurements (e.g., MacLeod et al., 1986), eye-tracking techniques (e.g., Burris et al., 2017; Peltola et al., 2015), event-related potentials (e.g., Peltola et al., 2009) and functional magnetic resonance imaging (e.g., Monk et al., 2006). Based on the methods used to study adult populations, the methods assessing attention biases have been divided into filtering, search, cuing and multiple task paradigms (Yiend, 2010). The facial expressions of emotions have been widely used as emotional targets in tasks of affect-biased attention especially when studying children (Burris et al., 2019; Fu & Pérez-Edgar, 2019). Threat bias has been studied also with pictures of non-social stimuli, such as pictures of snakes (Lobue & DeLoache, 2010). Next, we describe some tasks that are most widely used among children to study emotional attention biases.

A dot-probe task is one of the most used tasks to measure biases in attention orienting and more specifically attention engagement; it is based on measuring behavioral reaction times (Fu & Pérez-Edgar, 2019). In a seminal study by MacLeod et al. (1986), a pair of words appears on the computer screen, a target probe appears at the location of either of the words, and participants indicate the location of the probe, for example, by pressing a response button. One of the words is threat-related and the other contains neutral content. Shorter probe detection latencies preceded by a certain type of stimulus indicate an attention bias towards it. The task reflects exogenous, i.e., externally driven, attention, as it measures the reactions to the appearing stimuli. Later, several versions of the dot-probe task exist, and also pictures are used as stimuli (Fu & Pérez-Edgar, 2019). Despite its popularity, the dot-probe task has shown to have poor test-retest reliability and internal consistency (Fu & Pérez-Edgar, 2019; Kruijt et al., 2019). Recently, a modification of the dot-probe task has been created for infants using eye-tracking techniques to avoid complicated instructions and motor responses (Burris et al., 2017). In the infant version, a pair of pictures is presented for 500 ms on the screen proceeded by an asterisk probe appearing at the same location as one of the pictures. The latency of the gaze shift to the probe is measured (Burris et al., 2017).

Visual searching is another task for measuring attention orienting and biases in attention engagement using behavioral reaction times, in which the participant searches the target among distracting pictures in matrixes (e.g., 3 x 3 pictures) (Lobue, 2014; Öhman & Mineka, 2001). An enhanced response towards a specific target stimulus type compared to other stimulus types indicates an attention bias for it (Lobue, 2014; Öhman & Mineka, 2001). For example, shorter latencies to detect threatening targets among distractors compared to non-threatening targets among distractors indicate an attention bias for threat (Lobue, 2014; Öhman & Mineka, 2001).

A face-distractor overlap task can study biases in attention orienting, and more specifically, attention disengagement (Fu & Pérez-Edgar, 2019). In the task, a target stimulus is presented first at the center of the screen followed by an overlapping lateral stimulus with the target stimulus remaining visible (Aslin & Salapatek, 1975; Peltola et al., 2008). Also, this task reflects exogenous attention, as it measures the probability and latency of attentional disengagement from the target and attentional shift to the lateral stimulus. This task is applicable with eye-tracking technology (e.g., Peltola et al., 2015) but also with using video recording combined with manual frame-by-frame analyses (e.g., Peltola et al., 2008). The task is created to measure attention disengagement using saccadic latency to a lateral distractor and the probability to disengage attention from the central target picture to the lateral stimulus as the dependent variables (Kataja, Karlsson, et al., 2020; Leppänen et al., 2018; Peltola et al., 2018). In addition, the total dwell time on the facial expressions of emotion in the presence of a lateral distractor can measure the sustained attention to facial expressions (Morales, Brown, et al., 2017; Vallorani et al., 2021, 2023). The reliability of the task has been reported to be comparable among infants, when 2 to 10 trials per participant were available for odd-even split-half correlations (Peltola et al., 2018).

Free viewing of picture pairs combined with eye-tracking measurement has also been used in a few studies on infants and young children (Dodd et al., 2020; Lagattuta & Kramer, 2017; Libertus et al., 2017; Lobue & DeLoache, 2010). The task assesses both attention orienting, i.e., attentional engagement, as well as sustained attention. At the beginning of the task, when the picture pair first appears, the gaze behaviors reflect exogenous, i.e., externally driven attention. Later during the trial, when the pictures remain still on the screen, the gaze behaviors reflect more endogenous, i.e., internally driven attention.

In summary, different tasks are created to measure biases in different subcomponents of attention, but there is an on-going debate on the reliability of the measures. In the following chapter, we summarize the findings from the studies using these tasks to further the understanding of the normative development of affect-biased attention.

2.1.4 Normative Emotional Attention Biases During Early Childhood

Attention biases for emotional expressions of emotion have been studied relatively widely among infants, and also some studies on toddlers have been conducted although achieving cooperation with toddlers is a challenge for data collection (Fu & Pérez-Edgar, 2019). In this chapter, we will summarize previous findings of the attention biases for fearful, happy, angry and sad faces among typically developed children under 5 years.

The specific attention bias for fearful faces over neutral and happy faces has been a robust finding among infants between 7 and 8 months from different parts of the world (Finland: Kataja, Karlsson, et al., 2020; Peltola et al., 2008; Malawi: Pyykkö et al., 2019; Japan: Nakagawa & Sukigara, 2012; USA: Leppänen et al., 2018). It was first found in attention engagement among 7-month-olds (Kotsoni et al., 2001; Nelson & Dolgin, 1985). Higher attentional engagement for fearful faces over happy faces was also observed among infants between 8 and 14 months of age in a free-viewing task of paired pictures (Lobue & DeLoache, 2010). In addition, the bias in attentional disengagement is demonstrated in studies using a face-distractor overlap task with neutral, happy, fearful and angry faces, and some studies also included a non-face control picture (Kataja, Karlsson, et al., 2020; Leppänen et al., 2018; Nakagawa & Sukigara, 2012; Peltola et al., 2008; Pyykkö et al., 2018). According to longitudinal studies using eye-tracking and a face-distractor overlap task, attention bias for fearful faces emerges between 5–7 months (Peltola et al., 2009; Yrttiaho et al., 2014). After 2 years of age, this specific attention bias for fearful faces over both neutral and happy faces is no longer detected, but an attention bias for fearful faces versus neutral faces is still prevalent (Kataja et al., 2022; Leppänen et al., 2018; Peltola et al., 2018). Regarding other aspects of child development, 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 environment (Leppänen & Nelson, 2012). In parallel, the development of attachment to selected other people (e.g., the parents) strengthens, while friendly, undiscriminating responses to everyone else wanes (Bertenthal & Campos, 1984; Bowlby, 1969). In other words, changes in typical development of fear bias seem to occur at the same time as other significant changes in motor and social-emotional development.

A few previous studies on infants with attention bias for fearful faces have demonstrated an association between two different aspects of attention biases described in Cisler and Koster's (2010) model: behavioral aspect of attention biases for fearful faces, such as attentional disengagement, and possible underlying neural mechanisms of attention biases (Aatsinki et al., 2022; Tuulari et al., 2020; Yrttiaho et al., 2014). More specifically, a lower attention bias for fearful faces at 8 months of age has been related to larger left amygdala volumes at birth (Tuulari et al., 2020). In addition, attention bias for fear was related to the consistency in the attention-orienting network in a longitudinal study from 5 to 7 months of age combining eye-tracking and ERP measurements (Yrttiaho et al., 2014). Also, attention bias for fearful faces at 8 months has been related to a fecal microbiota composition that, according to other literature, has been stated to impact the development of emotion processing in the brain (Aatsinki et al., 2022). One other factor related to biological mechanisms is the child's genetic make-up. There are also studies investigating if one candidate gene, TPH2 and its allelic variant rs4570625, moderates the association between early life stress and attention bias for fearful faces at 5–8 months of age, but the associations have been observed in opposite directions in two studies (Forssman et al., 2014; Kataja, Leppänen, et al., 2020). Altogether, there is preliminary evidence on the association between fear bias and microbiota composition, amygdala volumes and cortical activity, but related studies remain scarce.

An attention bias for happy faces has been considered as positive attention biases and attention bias to reward (Morales, Pérez-Edgar & Buss, 2016). One previous study by Farroni et al. (2007) demonstrated an attention bias for happy faces over fearful faces right after birth. However, by 7 months of age, the attention bias for happy faces wanes, as infants start to show similar attention to happy and neutral faces and heightened attention to fearful faces (Leppänen et al., 2018; Peltola et al., 2009; Yrttiaho et al., 2014). During the early childhood years, between ages 2 and 5, some studies have found an attention-orienting bias for happy versus neutral faces (Burris et al., 2017; Dodd et al., 2020; Lagattuta & Kramer, 2017), whereas other studies found no evidence for it (Nakagawa & Sukigara, 2012; Pérez-Edgar et al., 2011). Similarly, some studies found an attentional bias for happy faces over neutral faces in sustained attention (Dodd et al., 2020) but others not (Lagattuta & Kramer, 2017).

Angry faces are considered as direct, social signals of threat, and attention biases for angry faces are considered as an attention bias for threat (Fu & Pérez-Edgar, 2019; Morales, Fu, et al., 2016). An attention bias for angry faces was demonstrated to be normative in attention orienting in a study using an age-appropriate, modified dot-probe task with angry and happy faces among children between 9 and 48 months (Burris et al., 2017) and among children between 4 and 24 months (Pérez-Edgar et al., 2017). In a free viewing of paired pictures, infants between 8 and 14 months of age showed shorter latencies to angry versus happy faces and to snakes versus flowers indicating a general attention-orienting bias for threat-relevant stimuli already during infancy (Lobue & DeLoache, 2010). On the other hand, when combining angry and neutral faces in free viewing of paired pictures, an attention bias for angry faces was not found among 4-year-olds (Dodd et al., 2020).

Attention patterns related to sad faces have been studied less during early childhood. In a previous study, an attention bias for sad faces compared to happy faces was found, but the attention bias was smaller than the attention bias for fearful and angry faces compared to happy faces (Lagattuta & Kramer, 2017). These results support the hypothesis that angry and fearful faces are more salient and more important than sad faces for survival due to the threat relevance of these expressions (Lagattuta & Kramer, 2017).

In summary, attention biases for emotional facial expressions seem to be specific in regard to the attention component, a child’s age and the stimuli that are compared. Because of the lack of longitudinal studies, the developmental changes in attention biases for happy, angry and sad facial expressions during early childhood are unknown. After discussing the previous literature on typical development of social-emotional attention biases that demonstrate attention biases generally for faces and for specific emotional facial expressions, we will next introduce literature on the development of attention biases and its associations to other aspects of social-emotional functioning.

2.2 Affect-Biased Attention and Social-Emotional Functioning

One motivation for research on emotional attention biases is its connections to other aspects of social-emotional functioning. The quality of the early parent–child interaction, a child's temperament and behavioral regulatory problems form a basis for a child's social-emotional development (Biringen et al., 2014; Bridgett et al., 2015; Hemmi et al., 2011; Rothbart et al., 2011). From toddlerhood on, internalizing symptoms, such as depressive and anxiety symptoms, and externalizing symptoms, such as ADHD and conduct problems, together with social-emotional competencies describe a child's social-emotional well-being (Briggs-Gowan et al., 2004; Briggs-Gowan et al., 2016). Previous literature has focused on the association between attention biases and psychopathology, mostly anxiety symptoms, on older age groups than infants and toddlers. More recently, the theories and empirical studies have tried to cover also the mechanisms within normative or typical functioning (Fu & Pérez-Edgar, 2019; Morales, Fu, et al., 2016). Thus, following roughly the historical order of the postulated theories, we will first present the literature on attention biases and psychopathology and then the more recent theories including aspects of typical development.

2.2.1 Theories on Attention Biases and Social-Emotional Functioning

During the second half of the 20th century, theories emphasizing cognitive processes over neurobiological mechanisms underlined the essential role that attention bias for threat had played in the etiology and maintenance of anxiety (Beck, 1976; Eysenck, 1992). Based on experimental studies, it was argued that anxiety facilitates the detection of signs for threat and danger, which has a considerable survival value, especially in potentially threatening environments (Eysenck, 1992). However, it was stated that overdevelopment of these threat-detecting processes concerning, for example, visual scanning, distractibility and hypervigilance, may lead to anxiety disorders (Eysenck, 1992). The first meta-analysis on the topic supported the hypothesis of heightened attention to threat among anxious individuals, when the results of the studies using dot-probe tasks were analyzed (Bar-Haim et al., 2007). An association was also found among children older than 7 years (Dudeney et al., 2015). In later studies, both attention bias toward threat (Pérez-Edgar et al., 2010, 2011; Roy et al., 2008) and away from threat (Brown et al., 2013; Grafton et al., 2016; Gunther et al., 2022) have been associated with anxiety symptoms and social withdrawal.

As the relation between attention bias toward threat and anxiety symptoms seemed to be causal (MacLeod et al., 2002), interventions for anxiety symptoms based on attention bias modification training (ABMT) were created (Harris & Menzies, 1998; MacLeod et al., 2002). The first studies showed it to be a promising new method having therapeutic value (Hakamata et al., 2010; Van Bockstaele et al., 2014). However, in a recent meta-analysis of randomized controlled trial studies on the baseline measurements of attention biases obtained in attention bias modification, clinically anxious individuals did not show heightened attention bias for threat when compared to healthy controls (Kruijt et al., 2019). One explanation is that the dot-probe task does not reliably measure attention bias at the individual level. Another possible explanation is that the relation between attention bias for threat and anxiety symptoms is more complex than assumed in the current theories (Kruijt et al., 2019).

Some more recent theories emphasize the role of attention biases while combining the results from genetic, neurobiological and cognitive studies (Fox & Beevers, 2016; Morales et al., 2019). In these theories, attention biases are seen as mediating or moderating factors between genetic and environmental factors and psychopathology (Fox & Beevers, 2016). During the first decade of the 21st century, literature reviews suggested that psychiatric research should focus more on the gene x environment interaction (Burmeister et al., 2008; Caspi & Moffitt, 2006). To explain why some individuals are more vulnerable than others to the effects of context adversity and to further the understanding of the gene x environment interaction, the concept of differential susceptibility was introduced (Belsky et al., 2007; Belsky & Pluess, 2009). The theory of differential susceptibility proposes that some individuals are more susceptible to adversity because of their genetic make-up, but the same genetic make-up makes them benefit from an enriching environment and an absence of adversity (Belsky et al., 2007; Belsky & Pluess, 2009). Therefore, the genes underlying this phenomenon could be conceptualized as "plasticity genes" rather than "vulnerability genes" (Belsky et al., 2007; Belsky & Pluess, 2009; Van IJzendoorn & Bakermans-Kranenburg, 2014). More recently, the Cognitive Bias (CogBIAS) model by Fox and Beevers (2016) proposed that attention biases may be another susceptibility factor, as the gene x environment interaction seems to be partly mediated by selective cognitive biases. For example, they proposed that negative cognitive biases shape the information that an individual is receiving from the environment, and, eventually with other factors, may lead to anxiety or depressive disorders. Conversely, positive attention biases shape the information that an individual is receiving and may support psychological well-being. Attention biases are one of the cognitive mechanisms that are suggested to mediate the gene x environment interaction among other cognitive biases, for example, in memory (Fox & Beevers, 2016).

Morales, Fu, et al. (2016) strengthened a developmental perspective to the attention biases and proposed in their model that emotional attention biases, i.e., affect-biased attention, have reciprocal rather than unidirectional connections to child social-emotional functioning. They also proposed that the role of affect-biased attention in a child's social-emotional functioning may change over the course of time, as the subcomponents of attention change during typical development. They also emphasize that the effects of affect-biased attention are not limited to attention bias for threat and anxiety outcomes, but, rather, attention biases are a domain-general mechanism that shape the information that an individual is receiving from the environment. However, there is lack of evidence regarding the causal mechanisms through which affect-biased attention and social-emotional functioning are connected during early childhood (Fu & Pérez-Edgar, 2019; Morales, Fu, et al., 2016).

A separate, more recent, branch of research has focused on affect-biased attention and social behaviors. According to the neurobiological models of ethical behaviors, an attention bias specifically for fearful faces has been related to the ability to behave ethically (Pfaff et al., 2008). More specifically, an ability to detect fear in others is a foundation for altruistic behavior, that is, selfless behavior in the service of other individuals' benefit (Marsh, 2016a). In contrast, impaired fear recognition has been related to psychopathology as an extreme opposite of prosocial behaviors (Marsh, 2016b). In addition, heightened sensitivity to fearful faces as well as children's fearfulness has been related to enhanced cooperative behaviors, and therefore, they have been seen as adaptive traits (Grossmann, 2022).

2.2.2 Theoretical Models of the Development of the Connection Between Affect-Biased Attention and Psychopathology

Recent theories state that it is crucial to understand the developmental origins of the relation between attention processes and anxiety symptoms (Amso & Scerif, 2015). Understanding this relation during the early years would further the understanding of the mechanisms behind the emergence of anxiety and social withdrawal as well as it would help identify the individuals at risk for anxiety (Burris et al., 2019). Although attention bias for threat has been studied widely in adults, adolescents and children, its developmental pathways are largely unknown (Burris et al., 2019; Field & Lester, 2010; Fu & Pérez-Edgar, 2019; Morales, Fu, et al., 2016). Field and Lester

(2010) have proposed three competing models about how information biases for threat change throughout development. First, the "integral bias model" proposes that there are individual differences in information processing biases that are innate constituents of emotion and remain stable from early childhood on and do not change during development. This assumption implies that information processing bias for threat can be detected at any stage of development, and it would continue across the lifespan, while the other markers of risk, such as the level of anxiety, may vary. Second, the "moderation model" proposes that information processing bias for threat is prevalent in all young children but diminishes during development. Development is moderated by other individual factors. In other words, an innate information processing bias for threat changes as a function of cognitive, emotional and social development, or it may be moderated by the level of anxiety. Third, the "acquisition model" proposes that information processing biases are not fully formed or present at all in young children, but they emerge with developmental maturation. This model proposes that acquiring an information processing bias may influence other individual factors, for example, the emergence of trait anxiety.

Based on the literature at the time of Field and Lester's (2010) review, these authors argued that the moderation model and the acquisition model had the strongest empirical support, but that no single model would explain all the findings. Therefore, they put forth the "hybrid model" that was later expanded by Morales, Fu, et al. (2016). The hybrid model proposes that there are innate attention biases that are based on individual factors and that the biases are moderated across the lifespan by both individual and environmental factors. These early, innate attention biases are manifested as more reactive attention patterns being alerting and orienting, and later, the executive attention systems start to modulate the attention biases. In addition, based on Todd et al. (2012) that proposes attention bias as part of emotion regulation, the hybrid model proposes that attention biases filter the information an individual receives from the environment, and, therefore, shapes the patterns of social-emotional functioning. Thus, attention biases may act to bind children in adaptive or maladaptive developmental trajectories. The hybrid model by Morales, Fu, et al. (2016) suggests that the development of affect-biased attention needs to be understood as the interplay between affect-biased attention and social-emotional functioning.

Studies on affect-biased attention and social-emotional functioning in infants and toddlers are few (Burris et al., 2019). The first longitudinal studies have demonstrated a low stability in affect-biased attention during the early years (Bierstedt et al., 2022; Kataja et al., 2022; Leppänen et al., 2018; Peltola et al., 2018), which may reflect a developmental change in attention biases possibly in relation to other social-emotional functioning. There are some previous studies on the connections between an infant's specific attention bias for fearful faces at 7–8 months of age and factors that are intrinsic and extrinsic to the child. In the following chapters, we will sum up existing literature on affect-biased attention and some key elements of infants' and toddlers' social-emotional functioning. Those key elements are infant temperament, infant behavioral regulatory problems, toddlers' social-emotional problems and competencies and the quality of maternal caregiving behaviors.

2.2.3 Affect-Biased Attention and Temperament During Early Childhood

The infant temperament can be defined as individual differences in reactivity and self-regulation (Rothbart & Derryberry, 1981). Based on the early conceptual work and factor analyses of the Infant Behavior Questionnaire, infant temperament consists of positive and negative affectivity (Gartstein & Rothbart, 2003). Negative affectivity includes distress to limitations and fear (Gartstein & Rothbart, 2003). Studies on affect-biased attention and social-emotional functioning have focused on features of temperament and especially negative affectivity, temperamental fearfulness and behavioral inhibition that are known to be related to a higher risk for internalizing problems (Fu & Pérez-Edgar, 2019; Henderson et al., 2015). Positive affectivity, in turn, includes subconcepts of smiling and laughter, duration of orienting, soothability and activity (Gartstein & Rothbart, 2003).

Negative affectivity and affect-biased attention have been studied widely, and many first-order correlations have been found (Fu & Pérez-Edgar, 2019). For example, negative affectivity has been related to heightened attention toward fearful faces (Nakagawa & Sukigara, 2012) as well as both toward (Pérez-Edgar et al., 2010) and away (Gunther et al., 2022; Morales et al., 2015) from threat. Interestingly, some studies demonstrate that infants with higher levels of behavioral inhibition or social fear show more stable attention patterns across tasks indicating that these children show more consistent patterns of affect-biased attention across tasks and over development (Bierstedt et al., 2022; Fu, Nelson, et al., 2019; Morales, Taber-Thomas & Pérez-Edgar, 2017). Recently, more complex findings have been reported between attentional patterns to emotional faces and temperament. Vallorani et al. (2021) found that infants with higher levels of temperamental negative affectivity and elevated maternal anxiety levels showed greater engagement with faces and better attentional disengagement capacities across several tasks of affect-biased attention. Positive affectivity is studied less, but in a previous study by Morales, Pérez-Edgar, et al. (2016), exuberant temperament that includes positive affectivity, impulsivity and high approach behaviors (Fox et al., 2001) was related to attention bias for happy faces. In sum, the possible confounding effect of infant temperament on affect-bias attention is important to control when studying the associations between affect-biased attention and other aspects of social-emotional functioning during infancy and toddlerhood.

2.2.4 Affect-Biased Attention and Early Behavioral Regulatory Problems

The association between attention bias for threat and anxiety disorders among children, adolescents and adults is well established, but the developmental pathways during early childhood are not yet known (Dudeney et al., 2015; Fu & Pérez-Edgar, 2019). Anxiety disorders are not applicable categories of psychiatric problems among infants and toddlers. Therefore, to study the early origins of the relation between anxiety symptoms and affect-biased attention, precursors of anxiety disorders or psychiatric symptoms relevant during infancy and toddlerhood need to be considered. During infancy and toddlerhood, previous studies have used temperamental behavioral inhibition as an early marker of a risk for later internalizing symptoms, which include anxiety symptoms (Pérez-Edgar et al., 2017). The study demonstrated an association between threat-related attention biases and temperamental behavioral inhibition in children younger than 2 years of age (Pérez-Edgar et al., 2017). During the preschool years, social withdrawal can be used as an early marker of risk for anxiety symptoms (Pérez-Edgar et al., 2011). A previous study showed that attention bias for angry faces moderate the association between behavioral inhibition in toddlerhood and social withdrawal at 5 years of age. More specifically, earlier behavioral inhibition was related to social withdrawal only in children who displayed attention bias for angry faces (Pérez-Edgar et al., 2011).

Behavioral regulatory problems are defined in the literature and in psychiatric diagnostic classification, such as DC 0–3, as excessive crying and problems in sleeping and feeding (Gross, 2016; Hemmi et al., 2011). The estimated prevalence for regulatory problems varies from 5% to 20% (Gross, 2016; Hemmi et al., 2011), and they are one of the most frequent reasons for parents to seek help for their infant from children's health professionals (Wolke, 2019). While temperament reflects more stable differences in behaviors between individuals (Bridgett et al., 2015; Rothbart et al., 2011), regulatory problems are more transient features of infant behaviors (Jusiene et al., 2015; Schmid et al., 2011). Also, infant temperament describes the normal variation of positive and negative affectivity and regulation (Rothbart & Derryberry 1981). Regulatory problems, in turn, cover problem behaviors and refer to regulatory behaviors more broadly and also in the regulation of physiological functions, such as sleeping (Gross, 2018).

Regulatory problems seen before 3 months of age may differ from the regulatory problems seen after 3 months of age (Emde, 1998; Thiel-Bonney & Cierpka, 2016). 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). Although the behavioral regulatory problems are related to maternal mental health and parent–child interactions, they may also exist independently throughout infancy (Olsen et al., 2019). The connections between regulatory problems 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 et al., 2015; Schmid & Wolke, 2014; Smarius et al., 2017). In addition, according to previous studies, behavioral regulatory problems during early infancy are the main predictor of combined regulatory problems later during childhood (Olsen et al., 2019). Multiple or persistent regulatory problems during early childhood have been related to ADHD and attention problems during adulthood (Bilgin et al., 2020). However, the predictive role of early regulatory problems in other psychological developmental areas remain unknown (Pauli-Pott et al., 2000; Toffol et al., 2019). Thus, both behavioral regulatory problems during infancy and affect-biased attention during the preschool years have been connected to internalizing problems later during childhood. However, no prior studies have investigated the association between affect-biased attention and behavioral regulatory problems during infancy, although it would further the understanding of early connections between affect-biased attention and psychiatric symptoms.

2.2.5 Affect-Biased Attention and Socioemotional Problems During Early Childhood

During toddlerhood, behavioral regulatory problems, i.e., problems in eating, sleeping and calming down, are still one of the key domains of social-emotional problems (Briggs-Gowan & Carter, 1998; Briggs-Gowan et al., 2016; Gross, 2016). In addition, two other main domains of social-emotional problems, which are internalizing and externalizing problems, can also be detected (Achenbach, 1966; Briggs-Gowan & Carter, 1998). These two domains can be divided into more distinct categories during late childhood, when internalizing problems are manifested, for example, through social withdrawal, depression and anxiety, and externalizing problems are shown, for example, through aggression, hyperactivity and defiance (Achenbach, 1966; Briggs-Gowan & Carter, 1998). Social-emotional problems detected as young as at 2 years of age may persist during childhood and even until preadolescence (Briggs-Gowan et al., 2006; Mesman & Koot, 2001). The BITSEA questionnaire for parents is developed to measure infants' and toddlers' socioemotional problems and adopts the dimensional approach to problem behaviors (Briggs-Gowan et al., 2004). There are cut-off scores for the BITSEA to categorize the children at risk, but adopting the dimensional approach to the socioemotional problems, the BITSEA scores can also be used as a continuous variable.

To our knowledge, there are no prior studies on the association between affect-biased attention and socioemotional problems during early childhood. However, many studies in school-aged children, adolescents and adults have shown an association between anxiety symptoms and attention bias toward threat that is an attentional preference for signals of threat (Bar-Haim et al., 2007; Cisler & Koster, 2010; Dudeney et al., 2015; Fu & Pérez-Edgar, 2019; Georgiou et al., 2005; Shechner et al., 2012, 2013) or attention bias away from threat, that is, attentional avoidance of signals of threat (Brown et al., 2013; Grafton et al., 2016; Gunther et al., 2022; Morales et al., 2015; Shechner et al., 2012). Currently, the literature lacks studies on the connection between social-emotional problems and affect-biased attention during toddlerhood. Therefore, research on this connection would provide crucial information about the development of the connection between affect-biased attention and precursors of psychopathology.

2.2.6 Affect-Biased Attention and Social-Emotional Competencies During Early Childhood

Social-emotional competencies refer to behaviors indicating that a child has achieved the age-appropriate goals in social-emotional development (Briggs-Gowan & Carter, 1998; Feldman & Masalha, 2010). Prosocial behaviors comprise, for example, helping, sharing and cooperating with others as well as social participation, setting limits and verbalizing one's own needs in a social context (Huber et al., 2019). Higher socioemotional competencies are related to, for instance, improved academic achievement and better mental health, and they play an important role in social-emotional development and well-being independently of social-emotional problems (Denham et al., 2009; Huber et al., 2019; Kaukiainen et al., 2002; Masten et al., 1995; Rubin et al., 2006).

Attention to faces and facial expressions of emotions have an inherent connection to social-emotional competencies, as they have been stated to be the foundations of social interaction and prosocial behaviors (Klin et al., 2015). Newborn infants' preference for faces, and, specifically for happy faces, is assumed to facilitate early bonding with a caregiver (Farroni et al., 2007; Ramsey & Langlois, 2002; Symons et al., 1998). An infant's and a caregiver's mutual attention to each other's faces and especially mutual eye contact promotes reciprocal interactions (Ramsey & Langlois, 2002). Evidence for this claim comes from studies showing that, for example, the direct eye-contact of a caregiver promotes the maintenance of attention to a caregiver, and an infant's eye contact encourages a caregiver to keep talking to an infant (Hains & Muir, 1996; Ramsey & Langlois, 2002; Symons et al., 1998). During the second year after birth, emotional facial expressions begin to influence toddlers' differential use of goal-directed behaviors (Walle et al., 2017). For example, toddlers at 24 months showed more social avoidance and security seeking in response to an adult's anger than an adult's sadness related to a broken toy, whereas they demonstrated more relaxed play in response to an adult's joy (Walle et al., 2017). The difference in behavior was not yet seen in 16-month-old toddlers (Walle et al., 2017). Thus, the possible interrelated connections between affect-biased attention and social-emotional functioning may change over the course of development.

Attention bias generally for faces and especially for fearful faces has been related to social-emotional competencies in previous studies (Bedford et al., 2015; Grossmann et al., 2018; Peltola et al., 2018; Rajhans et al., 2016). For instance, a longer first look at fearful faces at 7 months has been related to greater altruistic behaviors at 14 months of age (Grossmann et al., 2018). In addition, a faster fixation to fearful faces has been related to altruistic behavior cross-sectionally in 4–5-year-old children (Rajhans et al., 2016). However, a higher attention bias generally for faces, rather than an attention bias specifically for fearful faces, measured with eye-tracking tasks during infancy has been related to more frequent helping-related responses measured with behavioral tasks at 2 years of age (Peltola et al., 2018). In addition, a lower attention bias generally for faces during infancy has been connected to children's callous-unemotional traits, an extreme opposite of prosocial behaviors, at 2.5 years (Bedford et al., 2015) and at 4 years (Peltola et al., 2018). In other words, a higher attention bias for fearful faces during infancy has been related to positive outcomes in social development, but the studies on the topic remain sparse.

2.2.7 Affect-Biased Attention and Maternal Caregiving Behaviors During Infancy

Parenting behavior is a key element among environmental factors that may impact the development of affect-biased attention. The quality of parental caregiving behaviors has been associated with different aspects of a child's development, such as language development, social skills, school readiness and mental health (Belsky & Fearon, 2002; Biringen et al., 2014; Madigan et al., 2019; McLeod et al., 2007). Previous theoretical models have proposed that the parent-infant interaction, and especially, attachment security relates to the processing of a child's social and emotional information (Dykas & Cassidy, 2011). Several studies have shown an association between attachment security and affect-biased attention (Forslund et al., 2020; Kammermeier et al., 2020; Peltola et al., 2015, 2020). Infants who were securely attached at 14 months showed heightened attention to fearful faces as well as age-typical cortical discrimination of fearful faces from non-fearful faces at 7 months of age (Peltola et al., 2015, 2020). In a study by Forslund et al. (2020), disorganized attachment at 6–7 years of age links to lower attention to all facial expressions. Also, in a study by Kammermeier et al. (2020), securely attached children showed an increase in sustained attention to fearful and sad faces.

One important aspect of parental caregiving behaviors is the emotional availability (EA) of the parent–child dyad (Biringen, 1998, 2008). The concept of EA is based on 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). The Emotional Availability Scale (EAS) is created to measure four parental dimensions of EA, including sensitivity, structuring, non-intrusiveness and non-hostility, and two child dimensions, including responsiveness and involvement in caregiving behaviors. According to several previous studies, maternal EA connects to a child's emotion regulation and emotional understanding during infancy, toddlerhood and their preschool years (Biringen et al., 2014; Garvin et al., 2012).

There is one previous study by Kammermeier and Paulus (2022) investigating maternal EA and a child's attention to emotional facial expressions during early childhood. They assessed maternal sensitivity and non-intrusiveness as well as a child's sustained attention to happy, fearful, sad and neutral faces. They found that higher maternal sensitivity at the child's age of 12 months was associated with the child's increased attention to happy and sad faces at 24 months. In addition, less intrusive maternal behaviors at 12 months were related to increased attention to sad faces at 24 months. No cross-sectional correlations were found between maternal EA and a child's emotional attention (Kammermeier & Paulus, 2022). Taylor-Colls and Fearon (2015) investigated cross-sectionally maternal EA and infant neural responses to emotional faces and reported an association between a higher composite score of maternal EAS and larger neural responses to happy faces compared to neutral faces. The authors suggested that the infants of the mothers with higher EA encode or evaluate emotional expressions differently and maybe attach greater motivational value to them (Taylor-Colls & Fearon, 2015). However, previous studies investigating the association between parental EA and face processing with paradigms involving components of attention during infancy are few.

Although associations between the EA and a child's affect-biased attention have been studied less, 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 the individual variance in affect-biased attention and attention biases for fear or threat later during childhood (Gibb et al., 2011; Gulley et al., 2014; Lindblom et al., 2017; Loman & Gunnar, 2010; Pollak, 2015; Pollak & Kistler, 2002; Pollak & Sinha, 2002; Teicher & Samson, 2016; Tottenham et al., 2010). Second, maternal pre- and postnatal depressive and anxiety symptoms that are frequently linked with a 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 infant emotional attention, i.e., an increased attention bias towards fearful or angry faces (Fu & Pérez-Edgar, 2019; Kataja, Karlsson, et al., 2020; Kataja et al., 2019; Morales, Brown, et al., 2017; Otte et al., 2015). However, the results have been inconsistent, as the association between maternal anxiety symptoms and infant emotional attention biases has not been found in some studies (Aktar et al., 2022; Leppänen et al., 2018). Third, maternal personality features, more specifically positive affectivity, have been related to infants' higher attention to fearful versus happy faces (de Haan et al., 2004). Early caregiving behaviors, and, more specifically, EA may be one important mechanism through which the early family environment, maternal depressive and anxiety symptoms and maternal personality features may influence the affect-biased attention of the child. Thus, the quality of parenting behaviors would be the fourth important maternal factor possibly related to affect-biased attention during infancy.

2.2.8 Focus on Infancy and Toddlerhood

The "First 1,000 days" refers to the time period from conception to the child's 2nd birthday and has become a target for many projects and organizations such as the 1,000 Days (www.thousanddays.org), The First 1,000 Days Movement (https://parentinfantfoundation.org.uk/1001-days/) and The First 1000 Days in the Nordic Countries (https://first1000days.is). The rationale behind the focus on early development is its long lasting and even irreversible effects on well-being later during childhood and adulthood (Belsky & Fearon, 2002; Bilgin et al., 2020; Biringen et al., 2014; Briggs-Gowan et al., 2006; Denham et al., 2009; Dykas & Cassidy, 2011; Mesman & Koot, 2001; Olsen et al., 2019). In addition, brain development undergoes a growth epoch before 3 years of age when the brain has reached 80% of its maximum size (Bethlehem et al., 2022). Therefore, the present study focuses on early development of affect-biased attention and social-emotional functioning. The aim is to study during infancy and toddlerhood those connections that are found in older children and adults to provide information of the early origins of them. As previous studies on the topic are scarce, we focus on the general population, and the emphasis is on typical development.

3 Aims of the Study

Based on recent theories, affect-biased attention may have reciprocal connections to social-emotional functioning during development. It is well established that specific attention bias for fearful versus happy and neutral faces emerges between 5 and 7 months, it is prevalent among infants at 7–8 months and starts to wane by 12 months. However, little is known how this specific form of affect-biased attention is related to other aspects of the child's social-emotional functioning. This information is crucial to better understand the early development of social-emotional problem behaviors and competencies. Knowledge about these early associations is needed before more targeted interventions for problems in social-emotional functioning during early childhood can be developed. The aim of the current study was to further understand the association between the attention to emotional faces and especially to fearful faces, at 8 months of age and a child's social-emotional functioning (Figure 2). As factors intrinsic to the child, behavioral regulatory problems were studied at 3 months and socioemotional problems and competencies at 2 years. As a factor extrinsic to the child, the quality of maternal caregiving behaviors, more specifically maternal emotional availability, was investigated at the infant's age of 8 months. In addition, the aim was to explore the normative development of attention biases for emotional facial expressions between the less studied years of 2.5 and 5.

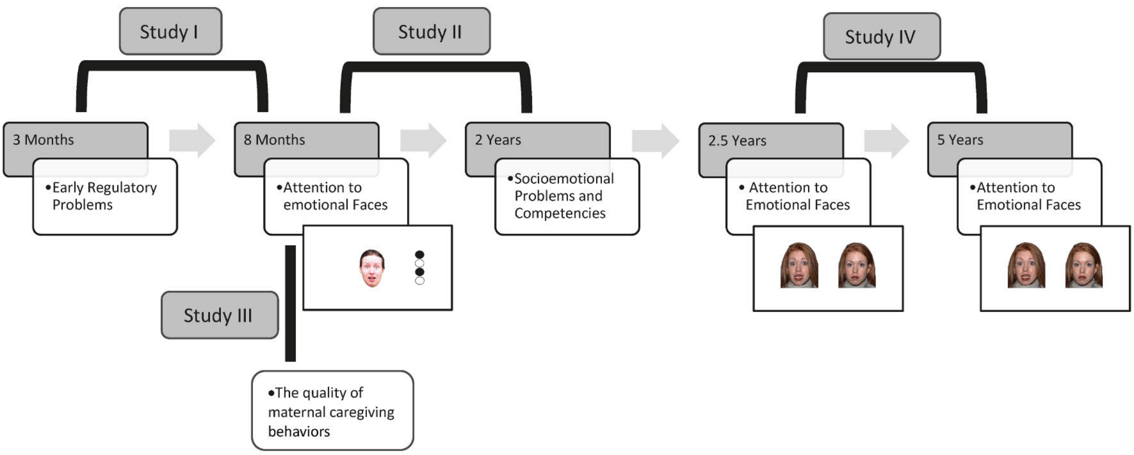

Figure 2. The associations investigated in Studies I–IV.

The specific aims were:

1. To study the association between behavioral regulatory problems at 3 months of age reported by parents and attention to emotional faces at 8 months of age. (Study I)
2. To study the association between an infant's attention to emotional faces at 8 months and socioemotional problems at 2 years of age reported by parents. (Study II)
3. To study the association between an infant's attention to emotional faces at 8 months and socioemotional competencies at 2 years of age reported by parents. (Study II)
4. To study the association between maternal caregiving behaviors, more specifically maternal emotional availability, and an infant's attention to emotional faces cross-sectionally at the infant's age of 8 months. (Study III)
5. To study attention biases for happy, fearful, angry and sad faces at 2.5 and 5 years of age. In addition, to study the change in attention patterns between the age groups as well as individual stability. (Study IV)

4 Materials and Methods

4.1 Study Design and Participants

The participants of these studies belong to a larger FinnBrain Birth Cohort Study (*n* = 3808, www.finnbrain.fi) that examines genetic and environmental influences on child development and health. The Cohort sample represents well the source population of Finland (Karlsson et al., 2018). The participants of the main Cohort were recruited from the South-Western Hospital District and Åland Islands in Finland between December 2011 and April 2015. A study nurse invited the mother and their spouses to this longitudinal study at the first trimester ultrasound visit at gestational week 12. Verified pregnancy and sufficient knowledge of either Finnish or Swedish were required. Before the children's age of 5 years, data were collected from parents of the whole cohort with questionnaires at gestational weeks 14, 24 and 34 and when the participating child was 3 and 6 months and 1, 2, 4 and 5 years old.

To study the effects of early-life distress on child development in more detail, a Focus Cohort was drawn from the main Cohort. The Focus Cohort forms a nested case–control study within the main Cohort. The Focus Cohort Criteria were based on preliminary analyses of the first 500 mothers' questionnaire data of depressive, general anxiety and pregnancy-related anxiety symptoms at gestational weeks 14, 24 and 34. The Focus Cohort was comprised of mothers reporting elevated distress symptoms at least in two different assessments (approximately the highest 25th percentile) and their controls reporting low levels of distress in all assessments. A more detailed description of the FinnBrain sample and the Focus Cohort Criteria is found in the Cohort Profile by Karlsson et al. (2018).

This study is a part of Child Development and Parental Functioning Lab, which was established to study the development of self-regulation with experimental measures as well as questionnaires. The infants and their parents of the Focus Cohort were invited to a neuropsychological study visit at the age of 8 months, which was corrected for prematurity, at 2.5 years from birth and at 5 years from birth. The study visits included eye-tracking measurements, measurements of temperament and executive functions and video-recordings of mother–infant interactions during free play. In addition, measurement of overall cognition was included in 2.5- and 5-year assessments. The 8-month measurements were carried out in FinnBrain laboratories at the University of Turku between March 2013 and July 2016, the 2.5-year follow-up between April 2015 and June 2018 and the 5-year follow-up between October 2017 and December 2021. The visits were conducted by either psychologists or advanced students of psychology.

The participants of Studies I–III comprised of the infants who participated in eye-tracking measurements at the study visit at 8 months of age. The flow chart in Figure 3 describes how the number of valid eye-tracking measurements and samples of the studies was formed. The free-play situation was added to the study protocol for the last study visits between October 2014 and June 2016. During this period, 354 mothers were contacted, and 197 mother–infant free-play situations were conducted. The participants of Study IV comprised of the children who participated in the eye-tracking measurement at least once at 2.5 and 5 years.

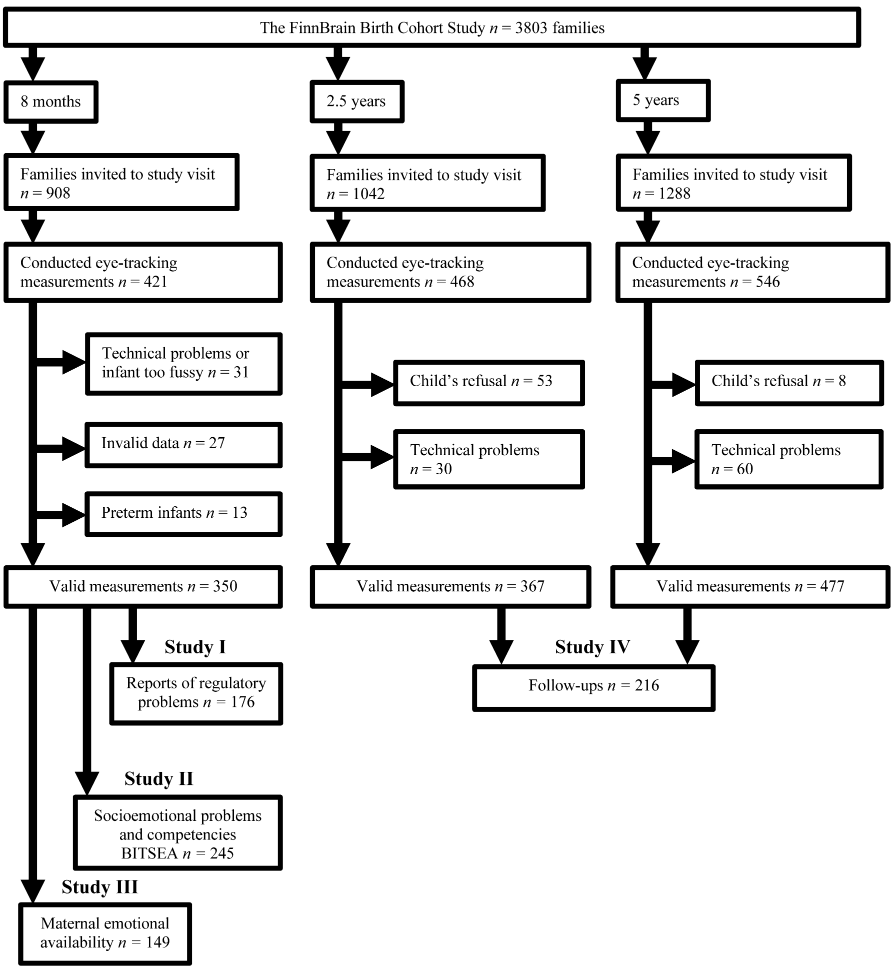

Figure 3. The flow chart of the recruitment process and data loss of the eye-tracking data.

4.2 Measures

4.2.1 Children's Attention to Facial Expressions

Children's attention to facial expressions were studied using eye-tracking measurements (Figure 4). Eye tracking was conducted in a dimly lit room. At 8 months and 2.5 years of age, children were seated on either of the parent's lap. At 5 years, children were seated on a chair, and one of the parents stood behind the child. Children were 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 tracker used a sticker on a child's forehead to estimate the position of the head. At 8 months and 5 years, the stickers were easily placed on the infants' forehead. At 2.5 years, many of the participants first refused to take the sticker or tried to remove it during the measurement. Therefore, we tried to help the participants feel comfortable using many small tips (e.g., introducing the sticker in the waiting room and researchers and parents wearing stickers). The researcher conducted the experiment with a host computer placed in the same room behind a curtain. Five-point calibration and validation routines were conducted before the tracking. The x- and y-coordinates for the estimated gaze locations were recorded at the frequency of 500 Hz.

Figure 4. Left: Host computer's view for the researcher. Right: The participant with her mother in front of the eye-tracking equipment preparing for the measurement at the 2.5-year study visit.

4.2.1.1 Face-Distractor Overlap Task

At 8 months of age, an overlap task (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 (Figure 5). The face stimuli were color images (15.4° x 10.8°) of facial expressions (i.e., two women posing with neutral, happy and fearful facial expressions) on a white background. 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°).

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 a 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 such that all the stimuli were presented 6 times but no more than 3 times in a row in one set of trials. One set comprised 24 trials and used the pictures of one actor. 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. The measurement consisted of two sets of trials comprising 48 trials altogether (12 trials per condition) with a small break with three, 4-second animations after the first set of 24 trials. If the infant was restless, short breaks were also held during the measurement. Eye tracking was terminated if the child became seemingly inattentive or fussy. The reliability measures for the task in the whole FinnBrain sample (n = 363) are presented in a study by Kataja et al. (2023).

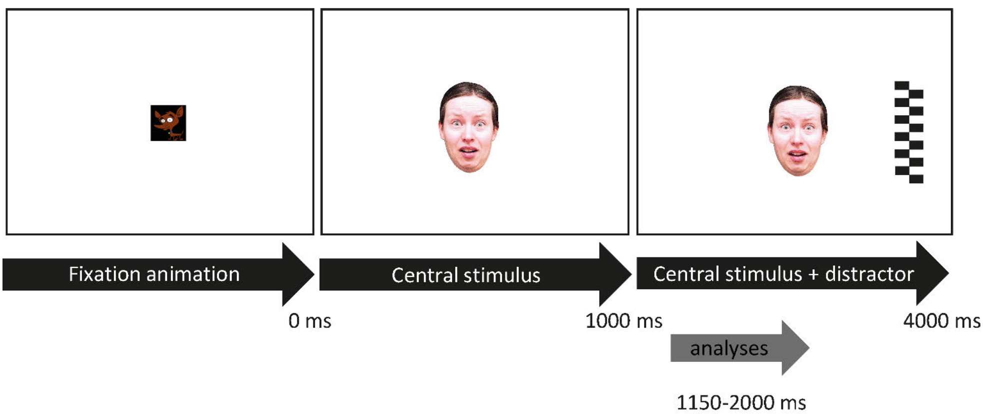

Figure 5. The overlap task: The timeline for presenting targets and the analyses period.

4.2.1.2 Free viewing of paired pictures

At 2.5 and 5 years of age, free viewing of face pairs with one neutral and one emotional face or scrambled-face control stimulus was conducted (Figure 6). The task consisted of 36 trials that presented face pairs for 4000 or 5000 ms. The researcher started the trial when a toddler was looking at the pre-trial audio-visual animation (e.g., a pig throwing a ball up and down) on the center of the screen. The face stimuli were color images of a woman posing neutral, happy, sad, fearful and angry with facial expressions adopted from the NimStim set (pictures of "Actor 1"; Tottenham et al., 2009). Each pair (i.e., neutral-happy, neutral-sad, neutral-fearful, neutral-angry, neutral-neutral and neutral-scrambled face) was presented 6 times in a semi-random order such that the same pair was presented no more than 2 times in a row. The researcher stopped the experiment if a child verbally or behaviorally indicated a willingness to stop even after a researcher's or a parent's kind encouragement to continue. The experiment was also stopped if the child became seemingly inattentive or upset.

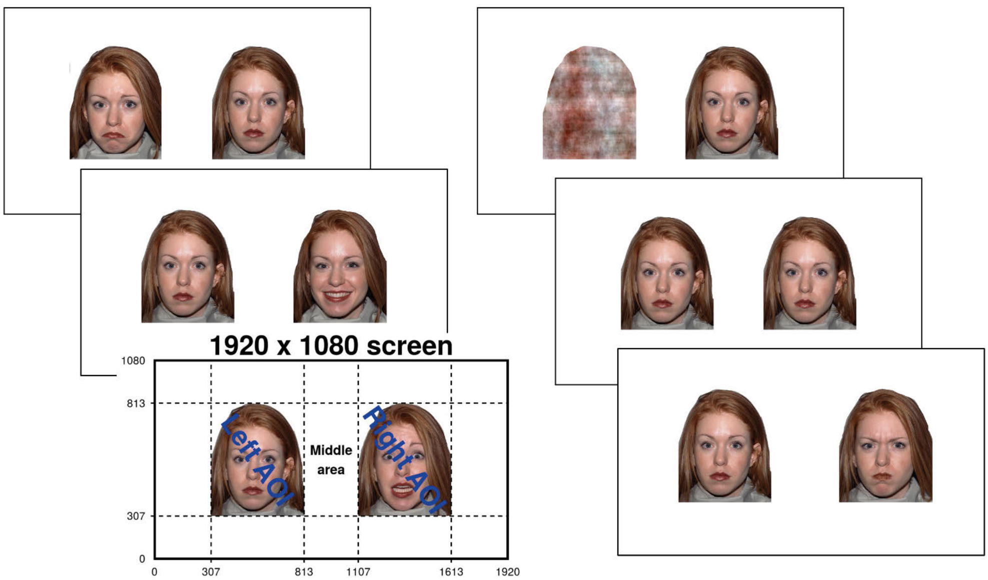

Figure 6. The stimuli and areas of interest (AOIs) of the face-pair task.

4.2.2 Early Behavioral Regulatory Problems

Questions on parental concerns about early regulation behaviors were included in the questionnaires for the whole cohort at the infant's age of 3 months. 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." The reports from both parents were used to control for a possible reporting bias. The distribution of parental reports is presented in Table 1. The regulatory problems (i.e., RP group; *n* = 66; 37.5%) were 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 regulatory problems" were applied (i.e., No-RP group; *n* = 110; 62.5%).

Table 1. The regulatory problems of infants at 3 months of age reported by mothers and fathers.

	All Participants (*n* = 176) %			**Regulatory Problems (RP) (*n* = 66) %**			**No Regulatory Problems (no-RP) (*n* = 110) %**		
Categories[1]	1	2	3	1	2	3	1	2	3
Maternal Report of Problems									
Feeding	56	38	6	26	58	28	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

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

4.2.3 Social-Emotional Problems and Competencies During Toddlerhood

The Brief Infant Toddler Social Emotional Assessment (BITSEA) was included in questions for the whole cohort, when the children were 2 years old. BITSEA is a brief version (42 items) of the Infant Toddler Social Emotional Assessment created for screening socioemotional problems and competencies among 12–36-month-olds in pediatric settings (Alakortes et al., 2015; Briggs-Gowan et al., 2004). Parents responded to statements using a 3-point Likert scale (0 = not true/rarely, 1 = somewhat true/sometimes, 2 = very true/often). The questionnaire had 31 items measuring socioemotional problems and 11 items measuring socioemotional competencies. Missing values were imputed with the mean (problems, max. 4 missing values; competences, max. 1 missing value was allowed). The descriptive statistics of parental BITSEA reports are presented in Table 2. In this sample, mothers reported more problems for boys than fathers reported. In addition, girls obtained higher competence scores than boys in both parent's reports (Mann-Whitney U-test, maternal report, p = .009; paternal report, p = .024). Both of these findings were reported also in a previous study (Alakortes et al., 2015). The mean of the parents' reports was used in the analyses when available. Otherwise, the report of either of the parents was used.

Table 2. Maternal and paternal mean scores, standard deviations of the BITSEA scales (problems and competencies) for girls and boys

BITSEA Scale n (maternal/paternal)	Mean (SD) Maternal report	 Paternal report	
Problems			
all (227/113)	7.31 (4.26)	6.67 (3.86)	p = .025[1]
girls (105/56)	6.75 (3.86)	6.98 (3.90)	p = .83
boys (122/57)	7.79 (4.53)	6.37 (3.84)	p =. 004
Competencies			
all (230/114)	18.23 (2.40)	17.11 (2.96)	p = .059
girls (106/56)	18.70 (2.12)	17.84 (2.63)	p = .10
boys (124/58)	17.82 (2.49)	16.40 (3.10)	p = .26

[1] Wilcoxon Test

4.2.4 Emotional Availability in the Mother–Infant Interaction

At the child's age of 8 months, the mother–infant interaction was video-recorded during a 20-minute free-play situation. A standard set of age-appropriate toys was offered, and the researcher 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 coders who were officially trained and certified (Biringen et al., 1998).

The EAS (Biringen et al., 1998) included four parent 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 a mother's behaviors that support the infant to learn and sense age-appropriate autonomy. It refers to the mother's ability to stimulate adaptive behavior and discourage maladaptive behavior by sending and receiving emotional signals. Non-intrusiveness refers to the ability to avoid interfering and interrupting the infant physically or verbally. A non-intrusive mother can withdraw when the infant seeks age-appropriate levels of independence. Non-hostility refers to the mother's ability to regulate her own negative emotions and to avoid expressing those emotions towards the infant. Hostility, on the other hand, refers to behaviors such as negative statements toward the infant or expressing frustration and boredom. Each dimension was coded using a 7-point Likert scale. The higher end of the scale refers to a healthier emotional connection between a mother and her infant. The interrater correlations describing the reliability of the coding were 0.80 for sensitivity, 0.72 for structuring, 0.85 for non-intrusiveness and 0.70 for non-hostility. The medians and interquartile ranges as well as correlations between the subscales are reported in Table 3. A composite score reflecting the construct of maternal EA in the mother–infant interaction was formed with four standardized and summed maternal scales.

Table 3. Median and interquartile ranges for the subscales of emotional availability and Spearman correlations between them.

	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

Table 4. Demographic information for Studies I–IV.

Background factor	Study I	Study II	Study III	Study IV 2.5-year-old group	Study IV 5-year-old group
Child Characteristics	*n* = 176	*n* = 250	*n* = 149	*n* = 367	*n* = 477
Sex (Girls), %	53	45	49	46	56
Gestational weeks at Birth	*Mean* = 40 *SD* = 1.17	*Median* = 40 *Range* = 38–42	*Median* = 40 *Range* = 38–42	*Mean* = 40 *SD* = 1.45	*Mean* = 40 *SD* = 1.74
Birth Weight	*Mean* = 3.616 *SD*= 459		*Median* = 3.595 *Range* = 2.530–4.940		
Maternal Characteristics	*n* = 176	*n* = 250	*n* = 149		
Age at the Delivery		*Median* = 32 *Range* = 21–44	*Median* = 31 *Range* = 21–44	*Mean* = 31 *SD* = 4.42	*Mean* = 31 *SD* = 4.48
Education, %					
High school/voc. school/lower	27	24	26	24	24
Tertiary vocational	34	33	36	31	28
University degree or higher	40	43	36	41	46
Depressive symptoms (EPDS)	*Mean* = 4, *SD* = 3.53[b]	*Median* = 4 *Range* = 0–22[a] *Median* = 3 *Range* = 0–21[d]	*Median* = 4 *Range* = 0–23[c]		
Paternal Characteristics	*n* = 176	*n* = 190		*n* = 235	*n* = 315
Age at the Delivery		*Median* = 32 *Range* = 21–48		*Mean* = 32 *SD* = 4.99	*Mean* = 32 *SD* = 5.26
Education, %					
High school/voc. school/lower	38	36		25	22
Tertiary vocational	36	37		20	22
University degree or higher	23	26		19	22
Depressive symptoms (EPDS)	3 (3.54)[b]	*Median* = 2, *Range* = 0–16[a] *Median* = 3, *Range* = 0–20[d]			

[a] gestational week 14; [b] at 3 months; [c] at 6 months; [d] at 2 years

4.2.5 Background Factors and Covariates

4.2.5.1 Demographic Information

Children's, mothers' and fathers' background characteristics were obtained from the questionnaires sent to the whole cohort sample and responded to by the parents (prenatally: gestational week 14, 24 and 34; postpartum: 3, 6 and 24 months). The information about the parent's age at the child's birth and delivery, education and monthly income, maternal parity and some information about the family structure was drawn from the questionnaire (Table 4). Additional information about an infant's characteristics, such as sex, gestational weeks at birth, birth weight and Apgar Score 5 minutes after birth was drawn from the Finnish Medical Birth Register administered by the National Institute for Health and Welfare (www.thl.fi).

4.2.5.2 Maternal Psychological Distress

The maternal depressive, anxiety and pregnancy-related anxiety symptoms were measured during pregnancy (gestational weeks 14, 24 and 34) to form the Focus Cohort and also postpartum (at 3, 6, and 24 months) as background information. Maternal depressive symptoms at 6-month 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). Pregnancy-related anxiety was measured with the Pregnancy-related Anxiety Questionnaire-Revised 2 (PRAQ-R2; Huizink et al., 2016).

4.2.5.3 The Child's Temperament

The child's temperament may have complex associations with affect-biased attention (Bierstedt et al., 2022; Fu & Pérez-Edgar, 2019; Morales, Fu, et al., 2016; Vallorani et al., 2021), and therefore, infant temperament, and, specifically, temperamental negative affectivity were controlled in the analyses of Study I as well as both negative affectivity and surgency/extraversion in Study II. Infant temperament was measured with the Infant Behavior Questionnaire Short Form Revised (IBQ-R, Gartstein & Rothbart, 2003; Putnam et al., 2014) at 6 months of age. In both Studies I and II, missing subscales of surgency/extraversion and negative affectivity were imputed with the mean (SUR: max. 2 missing subscales, max. 2 missing items in a subscale; NEG: max. 1 missing subscale, max. 2 missing items in a subscale).

4.3 Statistical Analyses

4.3.1 Gaze acquisition and raw data processing

In the face-distractor overlap task, the x- and y-coordinates of the estimated gaze location on the screen were recorded by the eye-tracker and information about the trial with the type of facial expression of the presented central stimulus and the location (left or right) of the distractor stimulus. 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 data collected from infants and other poorly cooperating participants. To measure attentional disengagement, we chose to use, as the dependent variable, the probability of disengagement during the time period from 150 ms to 1000 ms after the appearance of the distractor stimulus. The saccadic reaction time to the lateral stimulus was not used, as according to previous studies, in the case of fearful face, the infants disengage attention from the face stimuli in less than 50% of the trials (Kataja, Karlsson, et al., 2020; Peltola et al., 2008). Thus, saccadic latencies would provide information from less than half of the trials (see Hood et al., 1998). Valid trials were selected based on three inclusion criteria: 1) the infant fixated at least 70% of the time on the central stimulus before the attention disengagement or before the end of analyzing period, 2) there were no gaps longer than 200 ms in the recorded gaze data and 3) there were no gaps just before or just after the attention disengagement in the recorded data. Participants with at least three valid trials per condition (i.e., control picture, neutral, happy and fearful face conditions) were included in the final analyses. In the whole sample of infants (n = 363), the average number of valid trials per each condition was relatively high: scrambled face control stimulus = 8.90 (*SD* = 2.45), neutral = 9.02 (*SD* = 2.42), happy = 9.04 (*SD* = 2.42), and fearful = 9.29 (*SD* = 2.55).

In the free viewing of paired pictures, data were analyzed by using the fixation identification algorithm called, “identification by two-means clustering” (I2MC; Hessels et al., 2017), which was built for data with a wide range of noise levels and periods of data loss due to poorly cooperating participants. The areas of interest used in these analyses were squares tightly drawn around the stimuli (Figure 6). Only the trials where the child fixated in the middle of the screen at the beginning of the trial were considered valid trials and were included in the analyses, that is, the trials with a fixation in the middle of the screen at some point between 0 ms and 150 ms. Saccadic reaction times shorter than 150 ms from the stimulus appearance were assumed to be predictive (Kenward et al., 2017); therefore, only the saccadic shifts from the central stimulus to a peripheral target after 150 ms from the stimulus onset were included in the analyses. Furthermore, as the trial duration varied between the two age points, only the first 4000 ms was included in the analyses.

4.3.2 Eye-Tracking Variables and Estimated Quantities of Affect-Biased Attention

In Study I and III, 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. The disengagement variable was used in our analyses instead of more conventional variables using mean saccadic latency, as the disengagement occurred in less than 50% of valid trials in the fearful face condition. Thus, the mean saccadic latencies would cover less than half of the trials (Hood et al., 1998).

Values of the following eye-tracking quantities for a representative infant were estimated using mixed effects logistic regression 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, Karlsson, et al., 2020; Kataja et al., 2019). As previous studies have shown the specific influence of fearful faces on infant attention patterns at 8 months of age (Kataja, Karlsson, et al., 2020; Leppänen et al., 2018; Nakagawa & Sukigara, 2012; Peltola et al., 2008), 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 fear bias but compared the DP of the control stimulus to the DPs of the happy or neutral condition (Kataja, Karlsson, et al., 2020; Kataja et al., 2019). 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.

In Study II, DP was calculated as the proportion of gaze shifts from the central stimulus to the lateral distractor during the analysis period. The number of gaze shifts was divided by the number of all valid trials, and it ranged from 0 to 1. DP was calculated separately for each face condition (i.e., neutral, happy, fearful and scrambled face). Face bias was defined as the difference between the DPs for the scrambled face and the DPs for non-fearful faces, that is, neutral and happy faces (Yrttiaho et al., 2014). Fear bias was defined as the difference between the DPs for non-fearful faces (i.e., neutral, happy) and the DPs for fearful faces (Yrttiaho et al., 2014).

4.3.3 Study I: Regulatory Problems at 3 Months and Attention to Emotional Faces at 8 Months

In Study I, due to the lack of previous research, we made no assumptions of the directions of the associations, and our analyses were exploratory. DPs were modeled using mixed effects logistic regression (MELR) models with the binary disengagement variable (i.e., disengagement or no disengagement) as the response variable. All of our MELR models had their condition as the only infant-specific effect (i.e., random effect). Furthermore, as the DPs depended strongly on the trial number, we controlled 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.

To analyze the differences in the overall DPs between the RP groups, we used a model (Model 1; Figure 7a) in which the fixed effects were:

Model 1:
Condition + RP + TNS [+ 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 regulatory problem groups. Control variables were the maternal and paternal SCL-90 and EPDS scores at 3-month 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's temperamental negative affectivity. The missing values in the negative affectivity variable (n = 35) were imputed with the median.

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

Model 2:
Condition + RP [+ Control variables] + Condition × (RP [+ Control variables]) + TNS.

Here, we used contrast coding 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 are given in Table 5 and Figure 7b.

4.3.4 Study II: Attention to Emotional Faces at 8 Months and Socioemotional Problems and Competencies at 2 Years

In Study II, we first computed Mann-Whitney U-tests to examine if the face and fear biases were observed in the present sample as observed in the complete eye-tracking sample in the study by Kataja, Karlsson et al., 2020 (*n* = 363; Table 5). Then, two main analyses were conducted. First, a regression analysis was performed to predict BITSEA Problems by face bias and fear bias (Table 6) and tested against a Bonferroni-adjusted alpha level of .025 (.05/2). Possible confounding factors, such as an infant's sex, maternal age, education and depressive symptoms at the 1st trimester of pregnancy and 24-month postpartum and an infant's temperamental negative affectivity and surgency/extraversion were entered in the models as covariates. We used multiple imputation for the missing values of the covariates. In addition, we did some post-hoc analyses including a regression analysis to predict Internalizing Problems and Externalizing Problems by face and fear bias, as they constitute the BITSEA Problems scale. Second, a regression analysis was performed to predict BITSEA Competencies by face and fear bias (Table 10) and tested against a Bonferroni-adjusted alpha level of .025 (.05/2). In addition to these main analyses, we report Spearman correlations between the main variables and all continuous covariates. These covariates were maternal depressive symptoms at the first trimester of pregnancy and 24-month postpartum as well as an infant's temperamental negative affectivity and surgency/extraversion. A Mann-Whitney U-test was used to compare BITSEA Problems and BITSEA Competencies between boys and girls. A Kruskal-Wallis-test was used to compare BITSEA Problems and BITSEA Competencies among the three groups of maternal education level.

4.3.5 Study III: Attention to Emotional Faces and the Quality of Maternal Caregiving Behaviors at 8 Months

In Study III, 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). As in Study I, we controlled the effect of trial number dependency in the model (Kataja, Karlsson, 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. In addition, maternal age at the birth and delivery, education and depressive and anxiety symptoms at the infant's age of 6 months were controlled for, because they have been associated with maternal EA or attention for emotional faces in previous studies (Hakanen et al., 2019; Kataja, Karlsson, et al., 2020; Kataja et al., 2019). Model 3 (Table 11), thus, had the following fixed effects:

Model 3:
Intercept + Face + EA + Control variables + Face × (EA + Control variables) + TNS

Here, Face is a categorical variable with four levels (neutral, happy, fearful and control); EA is the EA composite score, and Control variables are maternal age, education, depressive and anxiety symptoms (a combined sum) and infant sex. 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 fear or face bias, 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 (i.e., fear bias) or to compare the average of happy and neutral conditions to the control stimulus (i.e., face bias).

The missing values in the control variables (see Table 4) 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 statistically significant.

4.3.6 Study IV: The Development of Affect-Biased Attention Between 2.5 and 5 Years

In Study IV, the following eye-tracking variables were used. To estimate the mean latency to first fixation on non-neutral faces as a measure of attention orienting in free viewing of paired-face pictures, the data consisted of trials, where the first fixation happened between 150 ms and 1000 ms and was directed toward the non-neutral face and were analyzed using a linear mixed model with the following structure (Model 4):

Model 4:
Latency ~ Face + Age + Face x Age + (Age | Child)

Here, Latency is the onset of the first fixation on a non-neutral face in milliseconds, Face indicates the type of non-neutral face (i.e., non-face control picture, happy, sad, angry or fearful face) and Age indicates the child’s age (2.5 or 5 years). The number of valid trials was controlled in the analyses. To analyze the reliability of the latency to the first fixation, Pearson correlations between the items, Cronbach's alpha and the split-half estimate of reliability were calculated and are presented in Table 5. The latency to the first fixation showed adequate internal consistency.

To evaluate the correlations of the latencies to the first fixation between the age points and faces, the mean latency to the first fixation, over the trials, was calculated for each child for each face at each age point, and, additionally, for all trials at each age point, after which Pearson correlations for these mean latencies were calculated.

We used the probability of the first fixation to a non-neutral face as the measure for attention-orienting bias. To estimate these probabilities and to test whether they differ from .50, trial-by-trial data were analyzed using a mixed effects logistic regression model. Valid trials, where the first fixation to the non-neutral face happened between 150 ms and 1000 ms, were included in these analyses. The structure of the model was:

Model 5:
FirstFixation ~ Face + Age + Face x Age + (Age | Child)

Here FirstFixation indicates whether a child fixates first on a neutral or non-neutral face. The number of valid trials was controlled in the analyses. To analyze the reliability of the attention-orienting bias, Pearson correlations between the items, Cronbach's alpha and the split-half estimate of reliability were calculated and are presented in Table 5. The attention-orienting bias variable showed poor to adequate internal consistency.

To evaluate the correlations of these probabilities between age points and faces, the probabilities were estimated by a simple ratio:

Trials with first fixation on non-neutral face / all trials (included in the analysis)

This was done for each child, for each face and at each age point, after which Pearson correlations for these estimates were calculated.

We used the same definition for bias in sustained attention as "attention bias" in Lagattuta and Kramer (2017), i.e., it was defined using total fixation time (TFT; between 150 ms and 4000 ms) as:

Model 6:
AttentionBias = (TFT_Non-neutral – TFT_Neutral) / (TFT_Non-neutral + TFT_Neutral)

where TFT_Non-neutral and TFT_Neutral mean total fixation time on the non-neutral and the paired neutral face, respectively. The values of the AttentionBias variable can thus vary between -1 and +1 with negative values indicating a bias for the neutral face and positive values indicating a bias for the non-neutral face and zero indicating no bias. AttentionBias was calculated for each valid trial, and the data were analyzed, including testing whether AttentionBias differs from zero, using a linear mixed model with the following structure:

Model 7:
AttentionBias ~ Face + Age + Face x Age + (Age | Child)

The number of valid trials was controlled in the analyses. To analyze the reliability of the variable bias in sustained attention, Pearson correlations between the items, Cronbach's alpha and the split-half estimate of reliability were calculated and are presented in Table 5. Bias in sustained attention showed poor internal consistency.

As above, to evaluate the correlations of AttentionBias between the age points and faces, the mean bias was calculated for each child, for each face, at each age point, after which Pearson correlations for these mean biases were calculated.

In each of the above models, latent individual quantities, latency to the first fixation and the biases were allowed to vary between the age points, i.e., random effects consisted of an intercept and Age for each child (indicated by [Age / Child] in the formulas). We also tried to fit a model where individual variation was also allowed between the faces, but those models did not converge, and, therefore, they were not used.

Table 5. Reliability estimates separately for each face condition and across all conditions: split-half reliability and Cronbach's alpha.

Variable	Age	Face	Split-half Reliability	Cronbach's Alpha [*CI* 95%]
Latency to the first fixation in non-neutral face	2.5 years	Non-face	0.52	.57 [.40, .70]
		Happy	0.47	.52 [.42, .61]
		Sad	0.63	.58 [.43, .68]
		Angry	0.43	.44 [.25, .58]
		Fearful	0.42	.48 [.32, .62]
		All conditions	0.78	.77 [.71; .81]
	5 years	Happy	0.40	.35 [.18, .49]
		Sad	0.51	.50 [.39, .58]
		Angry	0.44	.39 [.27, .50]
		Fearful	0.42	.42 [.31, .52]
		All conditions	0.78	.73 [.69; .78]
Attention-orienting bias	2.5 years	Non-face	0.46	.39 [.22, 52]
		Happy	- 0.67	- .55 [-1.00, -.25]
		Sad	- 0.64	- .44 [-.98, -.09]
		Angry	- 0.19	- .25 [-.70, .06]
		Fearful	- 1.06	- .78 [-1.42, -.35]
	5 years	Happy	- 0.14	- .05 [-.026, .11]
		Sad	- 0.31	- .39 [-.69, -.18]
		Angry	- 0.54	- .69 [-1.07, -.39]
		Fearful	- 0.22	- .15 [-.39, .04]
Bias in sustained attention	2.5 years	Non-face	0.53	.58 [49, .66]
		Happy	- 0.13	.07 [-.21, .27]
		Sad	0.09	.13 [-.08, .31]
		Angry	0.04	- .07 [-.35, .14]
		Fearful	0.24	.27 [.02, .43]
		All conditions	0.48	.52 [.35; .64]
	5 years	Happy	0.20	.24 [.09, .36]
		Sad	0.36	.31 [.17, .42]
		Angry	0.16	.12 [-.05, .27]
		Fearful	0.10	.15 [-.03, .29]
		All conditions	0.49	.46 [.29; .57]

4.3.7 Software Information

The statistical analyses were performed in R 3.5.2 (R Core Team, 2018) in Study I, in R 4.0.2 (R Core Team, 2020) in Study III and in R 4.0.5 (R Core Team, 2021) in Study IV. The mixed models were fitted using the lme4 package (Bates et al., 2015). The ggplot2 package (Wikham, 2009) was used to create Figure 7 (Study I), 8 and 9 (Study IV). In Study II, the statistical analyses were conducted using IBM SPSS Statistics 26.

4.4 Ethical Considerations

The study protocols of the FinnBrain Birth Cohort Study and all its substudies 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. The participating parents gave a written consent at every study visit for themselves and on the behalf of their children.

5 Results

5.1 General Results from the Overlap Task in Studies I–III

5.1.1 Overlap Task in Studies I–III

In Studies I, II and III, the overlap task with emotional faces was used. In each study, a different subsample of the original infant eye-tracking sample was used. The estimates for the median DPs were highest for the scrambled-face control picture, intermediate for the neutral and happy faces and lowest for the fearful face in all studies (Table 6), which is similar to previous studies by Kataja, Karlsson et al. (2020) with a larger FinnBrain infant eye-tracking sample (*n* = 363) or by Peltola et al. (2008), Leppänen et al. (2018) and Nakagawa et al. (2012) with different data sets.

Table 6. Disengagement probabilities for each face condition in Studies I–III.

	Study I		**Study II**	**Study III**
	RP group *n* = 66 Est. Median [95% *CI*]	**no-RP group *n* = 110 Est. Median [95% *CI*]**	**All *n* = 245 Sample Mean (*SD*)**	**All *n* = 149 Est. Median [95% *CI*]**
Scrambled Face	0.82 [0.76, 0.86]	0.84 [0.80, 0.84]	.80 (.20)	83 [.79; .86]
Neutral Face	0.60 [0.51, 0.69]	0.66 [0.60, 0.73]	.62 (.27)	.64 [.58; .69]
Happy Face	0.58 [0.51, 0.61]	0.64 [0.58, 0.69]	.61 (.26)	.63 [.58; .68]
Fearful Face	0.50 [0.41, 0.59]	0.42 [0.36, 0.49]	.47 (.29)	.49 [.43; .54]

Table 7. The main eye-tracking variables and background information for children excluded and included in Studies I–III

	Included in Study I *n* **= 176**	**Excluded from Study I** *n* **= 174**	**Included in Study II** *n* **= 250**	**Excluded from Study II** *n* **= 100**	**Included in Study III** *n* **= 149**	**Excluded from Study III** *n* **= 201**
Eye-tracking variables						
Control Stimulus	.80 (.21)	.79 (.22)	.80 (.20)	.78 (.24)	.80 (.22)	.79 (.20)
Neutral	.62 (.28)	.61 (.25)	.62 (.27)	.61 (.25)	.63 (.26)	.60 (.27)
Happy	.61 (.26)	.62 (.26)	.61 (.25)	.60 (.26)	.62 (.26)	.60 (.25)
Fearful	.48 (.29)	.45 (.26)	.47 (.28)	.47 (.26)	.50 (.28)	.44 (.27)
Face Bias	.19 (.24)	.18 (.23)	.19 (.24)	.17 (.23)	.17 (.23)	.19 (.24)
Fear Bias	.14 (.20)	.16 (.21)	.15 (.20)	.14 (.21)	.12 (.21)	.16 (.20)
Child Characteristics						
Sex (boys), %	47.2	59.8	54.8	50.0	49.0	56.7
First-borns, %	65.3	48.5 missing (*n* = 5)	60.7 missing (*n* = 3)	48.0 missing (*n* = 2)	57.5 missing (*n* = 3)	56.8 missing (*n* = 2)
Both parents in the same household, %	98.3 missing (*n* = 1)	95.5 missing (*n* = 40)	96.6 missing (*n* = 17)	98.7 missing (*n* = 24)	97.6 missing (*n* = 25)	96.8 missing (*n* = 15)
Gestational weeks at birth, *M* (*SD*)	40.11 (1.17)	40.02 (1.12)	40.09 (1.16)	40.01 (1.12)	39.90 (1.14)	40.19 (1.14)
Birth weight, *M* (*SD*)	3,616.46 (459.16)	3,627.69 (430.60)	3,631.31 (430.69)	3,598.59 (479.52)	3,597.57 (424.50)	3,640.03 (459.10)
Apgar score at 5 min., median (range)	9 (4–10)	9 (6–10)	9 (4–10)	9 (6–10) missing (*n* = 1)	9 (4–10) missing (*n* = 1)	9 (4–10)
Temperamental negative affectivity at 6 months	3.00 (.70)	3.00 (.86)	2.99 (.77)	3.02 (.82)	3.03 (.87)	2.97 (.71)
Maternal Distress 3 Months Postpartum						
EPDS, *M* (*SD*)	3.65 (3.53)	4.27 (3.99)	3.72 (3.49)	4.51 (4.39)	4.50 (4.22)	3.52 (3.33)
SCL-90/anxiety, *M* (*SD*)	2.34 (3.66)	2.81 (4.05)	2.40 (3.48)	2.98 (4.75)	3.29 (4.43)	2.04 (3.28)
Maternal Education						
< 12 years, %	26.7	29.9	23.6	40.0	26.2	29.9
12–15 years, %	33.5	28.7	32.0	29.0	36.2	27.4
> 15 years, %	39.8	37.9	42.8	29.0	35.6	41.3
missing		3.4	1.6	2.0	2.0	1.5
Paternal Distress 3 Months Postpartum						
EPDS, *M* (*SD*)	3.27 (3.54)	4.61 (4.38)	3.37 (3.63)	3.28 (3.51)	3.33 (4.18)	3.36 (3.20)
SCL-90/anxiety, *M* (*SD*)	2.38 (3.67)	3.00 (2.45)	2.43 (3.73)	2.39 (3.07)	2.53 (4.30)	2.35 (3.11)
Paternal Education						
< 12 years, %	38.1	19	25.2	37.0	23.5	32.3
12–15 years, %	35.8	10.3	26.0	16.0	24.8	21.9
> 15 years, %	23.3	35.6	18.0	7.0	15.4	14.4
missing	2.8	64.4	30.8	40.0	36.2	68.7
Monthly income (median)	2,001–2,500€	1,501–2,000€	2,001–2,500€ missing (*n* = 75)	1,501–2,000€ missing (*n* = 40)	1,501–2,000€ missing (*n* = 53)	2,001–2,500€ missing (*n* = 62)

5.1.2 Missing data

The original dataset included 350 valid eye-tracking measurements collected at the infants' age of 8 months among infants born full term. However, in Studies I-III, the analyses were conducted with the subsamples based on other measurements available: parent's report of regulatory problems at 3 months of age and socioemotional problems and competencies at 2 years or mother–infant free-play situation at 8 months. All parents received the questionnaires at 3 months and 2 years. The data included those children whose parents answered the questionnaires. The free-play situation was added only for 197 last study visits because of the lack of resources. In Table 7, the main eye-tracking variables and background factors are presented separately for children who were included and excluded in Studies I-III. In Table 8, the same variables are presented for children who participated at 2.5 years but did not participate in follow-up at 5 years in Study IV.

Table 8. The main eye-tracking variables at 2.5 years and background information for children participating or missing in the follow-up in Study IV.

	Included at 2.5 years in Study IV *n* = 216	**Missing from follow-up in Study IV *n* = 151**
Probability to first fixate to non-neutral face		
Nonface	.39 (.26)	.36 (.28)
Happy	.55 (.21)	.53 (.22)
Sad	.49 (.21)	.49 (.23)
Angry	.48 (.22)	.47 (.22)
Fearful	.52 (.24)	.54 (.24)
Fixation Time for Nonneutral Faces		
Nonface	425.91 (107.78)	428.11 (107.73)
Happy	399.65 (81.35)	402.12 (84.87)
Sad	402.76 (89.74)	413.49 (92.00)
Angry	393.82 (77.94)	418.60 (102.95)
Fearful	412.59 (87.49)	413.33 (86.52)
Child characteristic		
Sex (boys), %	53.7	52.3
Gestational weeks at birth, *M* (*SD*)	39.89 (1.40)	39.87 (1.52)
Birth weight, *M* (*SD*)	3,574.33 (498.44)	3,610.36 (502.51)
Maternal characteristics		
EPDS, *M* (*SD*)	3.95 (3.51)	3.77 (4.09)
SCL-90/anxiety, *M* (*SD*)	2.49 (3.40)	2.53 (3.91)
Education (missing)	2.3	21.2
< 12 years, %	22.2	23.8
12–15 years, %	30.1	24.5
> 15 years, %	45.4	30.5

5.2 Parent-Reported Regulatory Problems at 3 Months and Infant Attention to Emotional Faces at 8 Months (Study I)

In Study I, overall DPs during the overlap task did not differ between the infants with or without regulatory problems when no confounding factors were controlled (*OR* = 0.95, 95% *CI* [0.66, 1.37]) or when the effects of parental depressive and anxiety symptoms and infant temperament were controlled (*OR* = 0.94, 95% *CI* [0.60, 1.49]; Model 1).

General attention bias for faces versus non-faces did not differ between infants with regulatory problems and infants without regulatory problems (*OR* = 0.86, 95% *CI* [0.59, 1.27]) even when controlling for the parental depressive and anxiety symptoms and infant temperament (*OR* = 0.82, 95% *CI* [0.51, 1.32]; Model 2). However, the attention bias for fearful faces was statistically significantly lower (*p* = .00046) in infants with regulatory problems than in infants with no regulatory problems when controlling for the possible confounding factors of parental depressive and anxiety symptoms and infant temperament (*OR* = 2.03, 95% *CI* [1.47, 2.81]; Model 2) or testing against the Bonferroni-adjusted alpha-level of .0083 (.05/6). Estimated mean DPs for each face condition and face bias and fear bias are presented in Figure 6.

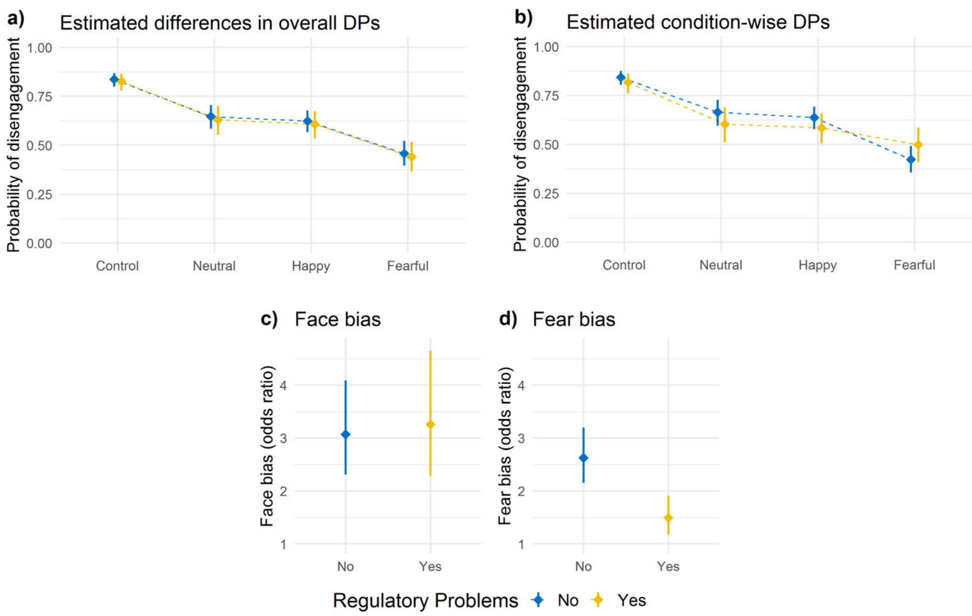

Figure 7. **a)** Estimated overall disengagement probabilities (DPs; Model 1 and 2) in the regulatory problem groups: yes and no and not controlling for the trial number dependency. **b)** Estimated DPs for the scrambled face control stimulus condition and neutral, happy and fearful face conditions. **c)** Odds ratio and 95% confidence interval for the face bias in the RP groups: yes and no. **d)** Odds ratio and 95% confidence interval for the fear bias in the RP groups: yes and no.

5.3 Infant Attention to Emotional Faces at 8 Months and Socioemotional Problems at 2 Years (Study II)

In Study II, we observed a positive correlation between fear bias and socioemotional competencies (r = .17, p = .009). In regression analyses, we used, as controlled factors, the background factors that correlated with either socioemotional problems or competences, which were maternal age, education and depressive symptoms at gestational weeks 14- and 24-month postpartum and an infant's sex and temperamental surgency/extraversion and negative affectivity. Regarding an infant's socioemotional problems, face and fear biases were associated neither with social-emotional problems nor with the subscales of internalizing and externalizing problems. A regression analysis predicting infants' socioemotional problems at 24 months by their face and fear biases at 8 months is presented in Table 9 (n = 245, *adj*. R^2 = .18, p < .001).

Table 9. Results of regression analysis of socioemotional problems by attentional face bias and fear bias (n = 242)

	Socioemotional Problems	
Variable	**Unstandardized Coefficients, Beta (Standard Error)**	**Standardized Coefficients, Beta**
Infant Sex	-0.38 (0.46)	-.049
Maternal Age	-0.019 (0.056)	-.020
Maternal education	-0.067 (0.30)	-.014
EPDS 1st trimester	0.12 (0.063)	.13
EPDS 24 mo postpartum	**0.16 (0.060)**	**.17**
SUR 6 mo	**-0.90 (0.35)**	**-.15**
NEG 6 mo	**1.97 (0.37)**	**.32**
Face Bias 8 mo	-0.011 (0.97)	-.001
Fear Bias 8 mo	1.04 (1.18)	.054

Statistically significant associations are bolded.
EPDS = Edinburgh Postnatal Depression Scale, SUR = Surgency/ Extraversion, Infant Behavior Questionnaire, NEG = Negative affectivity, Infant Behavior Questionnaire

5.4 Infant Attention to Emotional Faces at 8 Months and Socioemotional Competencies at 2 Years (Study II)

A regression analysis predicting infants' socioemotional competencies at 24 months by their face and fear biases at 8 months is presented in Table 10 (n = 242, adj. $R^2 = .12$, $p < .001$). Infant fear bias ($\beta = 1.70$, $p = .014$, $sr_i^2 = .025$) was positively associated with a child's socioemotional competencies after controlling for the effects of the confounding factors and testing against a Bonferroni-adjusted alpha level of .025, but the effect size was very small. Face bias was not related to a child's socioemotional competencies. ($\beta = .61$, $p = .28$, $sr_i^2 = .0050$). In sum, an infant's higher fear bias was related to better socioemotional competencies, but our data did not lend support for attention biases as an explanation for variance in socioemotional problems.

Table 10. Results of regression analysis of socioemotional competencies by attentional face bias and fear bias (n = 242)

	Socioemotional Competencies	
Variable	**Unstand. Beta (*SE*)**	**Stand. Beta**
Infant Sex	**0.79 (0.27)**	**.18**
Maternal Age	-0.045 (0.032)	-.089
Maternal education	0.25 (0.17)	.090
EPDS 1st trimester	**-0.10 (0.037)**	**-.19**
EPDS 24 mo postpartum	-0.024 (0.048)	-.048
SUR 6 mo	**0.69 (0.21)**	**.21**
NEG 6 mo	0.072 (0.22)	.021
Face Bias 8 mo	0.61 (0.56)	.067
Fear Bias 8 mo	**1.70 (0.69)**	**.16**

Statistically significant associations are bolded.
EPDS = Edinburgh Postnatal Depression Scale, SUR = Surgency/ Extraversion, Infant Behavior Questionnaire, NEG = Negative affectivity, Infant Behavior Questionnaire

5.5 Maternal Emotional Availability and Infant Attention to Emotional Faces at the Infant's Age of 8 Months (Study III)

In Study III, we analyzed how the composite score of maternal EA was associated with the DPs for neutral, happy and fearful faces and for the scrambled face control stimulus (Table 11). The *p*-values were adjusted for multiple comparisons using the Bonferroni correction. After controlling for maternal age, education and current distress, being the sum score of anxiety and depressive symptoms at 6 months postpartum, and infant sex, the association between lower maternal EA and higher DPs for fearful faces was significant (fearful, *OR* = 1.11, 95% *CI* [1.03, 1.19], *p* = .007, adj. *p* = .042; Model 3; Table 11). Significant associations between maternal EA and DPs for control stimulus or neutral and happy faces were not found (all adj *p*s > .05; Table 11).

Second, we analyzed how maternal EA was associated with the face and fear bias measures. After controlling for the selected covariates, we did not find any statistically significant associations between maternal EA and infants' face or fear bias (Table 11).

Table 11. The associations between a one-point increase in maternal Emotional Availability Scales (EAS) composite score and disengagement probabilities (DPs) for neutral, happy and fearful faces and the scrambled-face stimulus. The analyses are reported with control variables (i.e., maternal age, education, 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

5.6 Affect-Biased Attention at 2.5 and 5 Years of Age (Study IV)

5.6.1 Descriptive Statistics of the Fixation Patterns

The temporal pattern of fixations on each emotional face is presented in Figure 8. The spatial distributions of gaze across all face pairs are presented in Figure 9. To describe the potential habituation to the neutral face due to them being present in every trial, the correlation between trial number and total fixation time for neutral faces was calculated using trial-by-trial data. They were low at 2.5 years (r = -.12) and at 5 years (r = -.15).

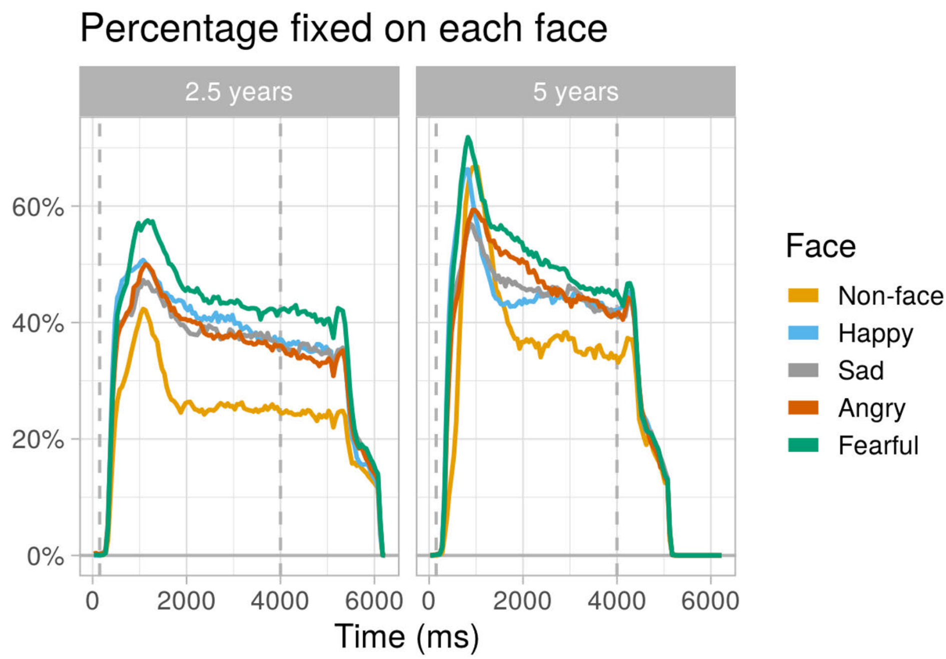

Figure 8. Timeline for attention to emotional faces during the free viewing of face pairs, i.e., for each face and for each 50 ms time interval, as the percentage of all trials in the study where the children fixated at that face. The dashed grey lines are at 150 ms and 4000 ms, i.e., the limits of the time interval from which the data were included in the study.

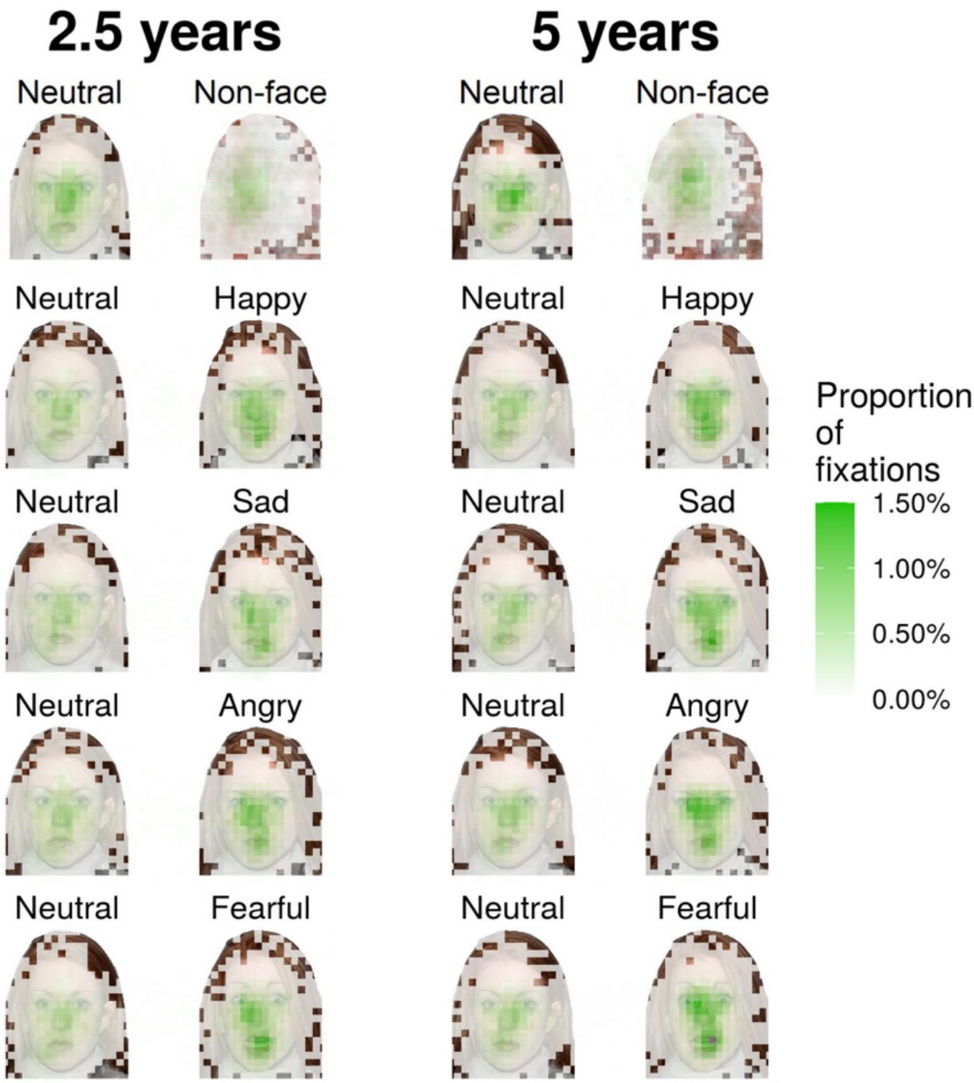

Figure 9. Spatial distributions of gaze across all face pairs at 2.5 and 5 years of age. The color indicates the proportion of fixations at each 30 x 30-pixel area with the darker green color indicating that the participants fixated more frequently on that area and no added color means no fixations on that area. Fixations made between 150 ms and 4000 ms from stimulus onset in valid trials from all the children for each time point and for each face. Proportion of fixations = number of fixations on the 30 x 30-pixel area / number of fixations on the whole screen. Here, only the trials where the neutral face was on the left side were considered.

5.6.2 Attention Orienting: Latency to the First Fixation on Non-Neutral Faces

Estimated mean latencies to the first fixation on non-neutral faces from Model 4 are presented in Figure 10 separately for the non-face picture and the happy, sad, angry and fearful faces. The trials, where the first fixation was in the neutral face, were excluded. We found no statistically significant differences between the latencies to the first fixation for happy, sad, angry or fearful faces or non-face pictures within either age group (Figure 10). However, the latencies to the first fixation shortened statistically significantly between 2.5 and 5 years in the conditions of happy, sad, angry and fearful faces (Table 13). All statistically significant findings remained as such after controlling the effects of the number of valid trials.

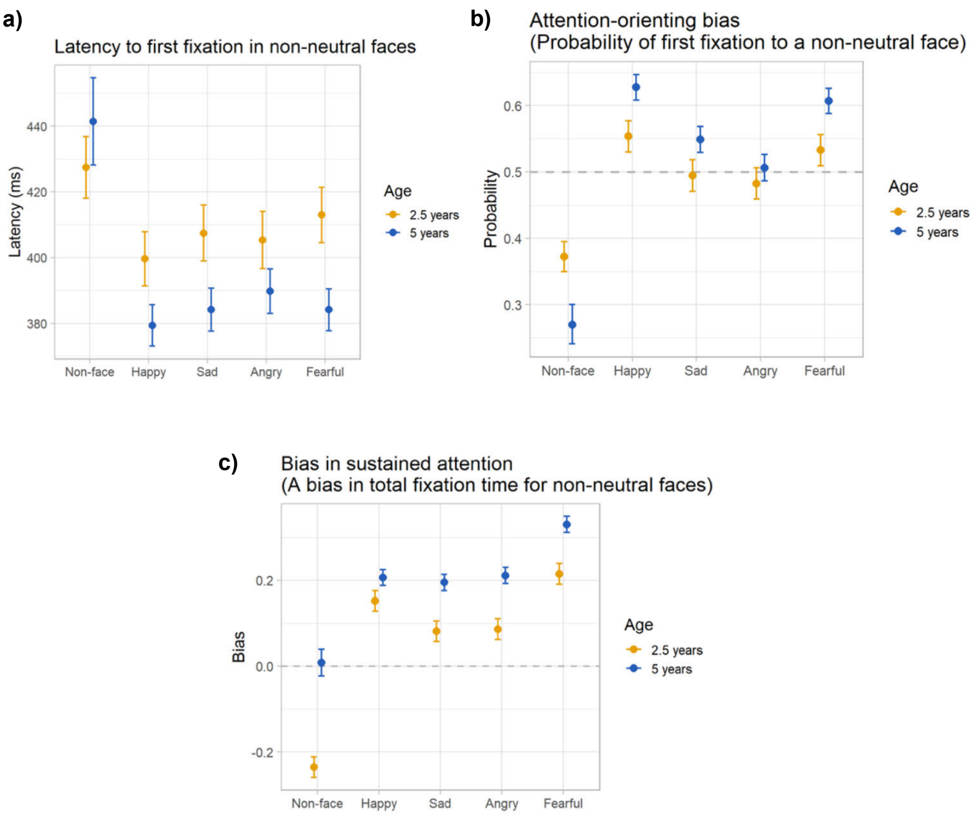

Figure 10. a) Estimated mean latencies to the first fixation on non-face pictures from Model 4, and happy, sad, angry and fearful faces for the trials where the first fixation was in a non-neutral face. **b)** Probability to fixate first on the non-face picture, happy, sad, angry or fearful face from Model 5. The values above the dashed grey line represent an attention-orienting bias towards the stimulus. **c)** Estimated mean bias in sustained attention from Model 6 for happy, sad, angry and fearful faces and for the non-face picture. The error bars denote 95% *CI*s.

Table 12. Differences in bias in sustained attention for different face stimuli within one age point.

			Estimated Difference [*CI* 95%]	*p*
2.5 years	Non-face	Happy	0.388 [0.357; 0.419]	<.001
	Non-face	Sad	0.317 [0.286; 0.348]	<.001
	Non-face	Angry	0.323 [0.291; 0.354]	<.001
	Non-face	Fearful	0.451 [0.420; 0.482]	<.001
	Happy	Sad	-0.070 [-0.102; -0.040]	<.001
	Happy	Angry	-0.066 [-0.097; -0.035]	<.001
	Happy	Fearful	0.063 [0.031; 0.094]	<.001
	Sad	Angry	0.005 [-0.026; 0.037]	.735
	Sad	Fearful	0.134 [0.102; 0.165]	<.001
	Angry	Fearful	0.128 [0.097; 0.160]	<.001
5 years	Non-face	Happy	0.198 [0.162; 0.234]	<.001
	Non-face	Sad	0.187 [0.151; 0.223]	<.001
	Non-face	Angry	0.203 [0.167; 0.239]	<.001
	Non-face	Fearful	0.322 [0.286; 0.358]	<.001
	Happy	Sad	-0.011 [-0.037; 0.014]	.391
	Happy	Angry	0.005 [-0.021; 0.031]	.700
	Happy	Fearful	0.124 [0.098; 0.150]	<.001
	Sad	Angry	0.016 [-0.009; 0.042]	.213
	Sad	Fearful	0.135 [0.110; 0.161]	<.001
	Angry	Fearful	0.119 [0.093; 0.145]	<.001

5.6.4 Attention-Orienting Bias: Probability of the First Fixation to a Non-Neutral Face

The estimated probabilities of the first fixation to a non-neutral face from Model 5 are presented in Figure 10. At 2.5 years of age, the probability of the first fixation to a happy or a fearful face was higher than to a neutral face (Figure 10). At 5 years of age, the probability of the first fixation to a happy, sad and fearful face was higher than to a neutral face (Figure 10). The attention-orienting bias did not differ statistically significantly from .50 for angry faces at 2.5 or 5 years, but it differed statistically significantly from .50 for happy and fearful faces at 2.5 years and for happy, sad and fearful faces at the age of 5 years (Figure 10). In addition, the probability of the first fixation to a non-face picture was lower than to a neutral face at both age points indicating an attention-orienting bias for neutral faces compared to non-face patterns. All statistically significant findings remained as such after controlling the effects of the number of valid trials. Based on Model 5, there was a statistically significant increase in the probability of first fixating on a happy, sad and fearful face between 2.5 years and 5 years (Table 13).

Table 13. Differences in latencies to the first fixation on the non-neutral face, attention-orienting bias and bias in sustained attention for each face stimulus between the age points (2.5 vs. 5 years).

	Estimated Difference	***CI* 95%**	***p***
Latency to the first fixation in non-neutral face			
Non-face	13.015	[-1.942, 29.772]	0.085
Happy	-20.250	[-30.029, -10.471]	<.001
Sad	-23.260	[-33.462, -13.059]	<.001
Angry	-15.543	[-25.926, -5.160]	0.003
Fearful	-28.820	[-38.775, -18.866]	<.001
Attention-orienting bias			
Non-face	0.622	[0.520, 0.745]	<.001
Happy	1.359	[1.199, 1.539]	<.001
Sad	1.245	[1.101, 1.408]	<.001
Angry	1.100	[0.972, 1.244]	.130
Fearful	1.355	[1.196, 1.534]	<.001
Bias in sustained attention			
Non-face	0.244	[0.025, 0.283]	<.001
Happy	0.054	[0.024, 0.084]	<.001
Sad	0.114	[0.084, 0.0144]	<.001
Angry	0.125	[0.095, 0.155]	<.001
Fearful	0.115	[0.085, 0.145]	<.001

5.6.5 Bias in Sustained Attention: Bias in Total Fixation Time for Non-Neutral Faces

Bias in sustained attention was estimated based on the total fixation times for non-neutral faces compared to the total fixation times for neutral faces. Based on Model 6, at the age of 2.5 and 5 years, the bias in sustained attention differed statistically significantly from zero for happy, angry, sad and fearful faces compared to neutral faces (Figure 10). At 2.5 years of age, the estimated bias in sustained attention was highest for the fearful faces, intermediate for happy faces and lowest for the sad and angry faces (Table 12, Figure 10). We found no statistically significant difference between a bias in sustained attention for sad and angry faces (Table 12). There was also a statistically significant bias in sustained attention for the neutral face versus the non-face picture (Figure 10). At the age of 5 years, the bias in sustained attention for fearful faces was still the highest, and no differences were observed between the biases for happy, sad and angry faces (Table 12, Figure 10). In addition, the bias in sustained attention for neutral faces versus non-face patterns was no longer seen at 5 years (Figure 10). The bias in sustained attention for all non-neutral faces increased statistically significantly between 2.5 and 5 years (Table 13). All statistically significant findings remained as such after controlling the effects of the number of valid trials.

5.6.6 Correlations Between 2.5 and 5 Years

There were small but statistically significant correlations ($r = .15 – .31$) between the two age points in the latencies to first fixation for happy, sad, angry and fearful faces (Table 14). These small correlations were not only between the same types of stimuli, that is, between the same facial expressions at different age points but also between different emotional facial expressions at different age points. There was a moderate correlation between 2.5 and 5 years in the mean latencies to the first fixation of all trials ($r = 0.36$ [0.24; 0.47], $p < .0001$). We found no statistically significant correlations between the 2.5- and 5-year measurements of the probability to first fixate on any non-neutral facial expression (all *r*s < .15). A general bias in sustained attention for faces (i.e., neutral face vs. non-face picture) at 2.5 and 5 years was correlated, but the correlation was small ($r = .16$, $p = .033$). Similarly, there was a small correlation between the bias in sustained attention for angry faces at 2.5 and 5 years ($r = .25$, $p = .001$).

Table 14. Pearson correlations for latencies to the first fixation on the non-neutral faces between different facial expressions and different age groups (at 2.5 and 5 years old).

	2.5 years					**5 years**			
	Non-face	**Happy**	**Sad**	**Angry**	**Fearful**	**Non-face**	**Happy**	**Sad**	**Angry**
2.5 years									
Happy	.30***								
Sad	.29***	.31***							
Angry	.29***	.36***	.30***						
Fearful	.35***	.37***	.36***	.39***					
5 years									
Non-face	.20	.20	.11	.23*	.28**				
Happy	.13	.21**	.16*	.25***	.21**	.22**			
Sad	.09	.21**	.17*	.21**	.14*	.36***	.35***		
Angry	.23**	.21**	.23**	.25***	.26***	.35***	.39***	.45***	
Fearful	.05	.17*	.13	.17*	.23**	.35***	.39***	.44***	.46***

The correlations within an age group are presented on a white background and the correlations between age groups on a grey background. The correlations between the same facial expressions at different age points are presented on a darker gray background.

6 Discussion

This study had two main aims. The first aim was to explore the social-emotional attention biases at 8 months of age and social-emotional functioning. The aspects of social-emotional functioning that were selected to this study were infants' behavioral regulatory problems, toddler's socioemotional problems and competencies and the quality of maternal caregiving behaviors, as they are among key elements forming the basis of social-emotional well-being later during childhood (Biringen et al., 2014; Bridgett et al., 2015; Briggs-Gowan et al., 2004, 2016; Hemmi et al., 2011). The second aim was to study the normative development of social-emotional attention biases from toddlerhood to preschool age. The subjects of this study consisted of the children of the families participating in the FinnBrain Birth Cohort Study, which is a general population-based longitudinal study established in 2010. For the present study, the children and their families were followed from pregnancy to the child's age of 5 years.

6.1 Behavioral Regulatory Problems at 3 Months and Attention to Emotional Facial Expressions at 8 Months

At 8 months of age, infants typically show a clear attention bias for fearful faces versus happy and neutral faces (Leppänen et al., 2018; Peltola et al., 2008; Yrttiaho et al., 2014). In Study I, infants with behavioral regulatory problems at 3 months showed a decreased attention bias for fearful faces compared to infants without regulatory problems. The regulatory problems included worries about excessive crying and problems in sleeping and feeding. This finding remained statistically significant after controlling for the maternal depressive and anxiety symptoms and the infant temperamental negative affect indicating an independent role played by regulatory problems in relation to the decreased attention bias for fearful faces. This was the first study to explore this connection. Previous studies have showed a long-term association between persistent or multiple regulatory problems and internalizing and externalizing symptoms as well as ADHD among children and even among adults (Bäuml et al., 2019; Hemmi et al., 2011; Olsen et al., 2019), but the association between early RPs and social-emotional functioning later in childhood is still under debate (Toffol et al., 2019). Our results are in line with one previous study on early regulatory problems, which demonstrates that higher levels of regulatory problems at 1 month of age are related to other aspects of a child's self-regulation, such as problem-solving skills and temperament (Toffol et al., 2019).

We found no association between RPs and the overall probability of disengaging from faces. This association was studied, as an infant's ability to disengage attention from distressing objects is one of the first forms of self-soothing behaviors (Field, 1981; Lewkowicz & Turkewitz, 1981; Rothbart et al., 2011). Previously, an infant's temperamental soothability relates to the overall ability to disengage attention from one object to another (Crockenberg & Leerkes, 2004; Johnson et al., 1991; Leppänen et al., 2011; Nakagawa & Sukigara, 2019b). These findings are in line with the prediction that behavioral regulatory problems and infant temperament may have different connections to other aspects of social-emotional functioning. However, this non-result should be interpreted with caution, as it might also be explained by some limitations in Study I.

At least two possible explanations for the association between early regulatory problems and a lower attention bias for fear, being a developmental delay account and an arousal account, can be proposed. According to the developmental delay account, a lower fear bias at 8 months of age may reflect a delayed or altered development of affect-biased attention during infancy. At 8 months of age, an attention bias for fearful faces emerges in normative development (Leppänen et al., 2018; Peltola et al., 2009; Yrttiaho et al., 2014). Even a short delay in the development may manifest in a lower fear bias or absence of the bias. Early regulatory problems and a lower fear bias reflect a slower or altered pace of neural maturation. For example, an attention bias for fear at 7–8 months associates with left amygdala volumes (Tuulari et al., 2020) and to consistency in the attention orienting network (Yrttiaho et al., 2014). Both the amygdala and attention-orienting network might also play a role in regulatory problems, as they both connect to the development of self-regulation (Bridgett et al., 2015; Posner et al., 2014).

According to the arousal account, on the other hand, the decreased fear bias among the infants with regulatory problems may reflect their higher levels of arousal. According to a previous study, there is a link between attention and arousal in children (Woody et al., 2019). There is also evidence that negative facial expressions or, more precisely, fearful faces, may facilitate attentional shifting and visual searching (Kleberg et al., 2018; Nakagawa & Sukigara, 2019a; Yiend, 2010), which may lead to a higher probability of disengaging attention from a fearful face, and, thus, decrease the attention bias for fearful faces. Applied to the findings of Study I, fearful faces may lead to a higher arousal in infants with regulatory problems, and, therefore, enhance vigilance toward lateral distractors, specifically in the fear condition. As arousal links to unselective attentional responses in previous studies

(Kleberg et al., 2018), infants with regulatory problems may have high general arousal levels, and then, the salient stimuli, such as fearful faces, do not attract their attention over other facial expressions.

6.2 Attention to Emotional Facial Expressions at 8 Months and Socioemotional Problems at 2 Years

The findings from Study II did not support the hypothesis on the association between attention bias for fearful faces at 8 months of age and socioemotional problems at 2 years. The bias in attentional disengagement from fearful faces was measured with eye tracking and the overlap task with centrally presented neutral, happy and fearful faces and lateral distractors. Socioemotional problems were measured with the BITSEA questionnaire reported by parents. The analyses were controlled for the effects of maternal age and level of education and depressive symptoms and infant temperament. To our knowledge, this is the first study to explore this association during early years. This non-supported hypothesis was based on a well-established finding on the association between an attention bias for threat and fear and anxiety symptoms in school-aged children, adolescents and adults (Bar-Haim et al., 2007; Cisler & Koster, 2010; Dudeney et al., 2015; Georgiou et al., 2005). The BITSEA's socioemotional problems subscale used in this study conceptually covers anxiety symptoms, as they belong to the category of internalizing problems (Briggs-Gowan et al., 2004). Thus, our aim was to investigate if this association already exists right after the emergence of attention bias for fear at 8 months of age. However, the null result should be interpreted with caution, as the possible association may not have been detected due to the limitations of the present study.

There are several possible explanations for the absence of the hypothesized effect. Attention bias for a fearful face at 8 months of age relates to socioemotional problems during toddlerhood, but the BITSEA problem scale does not detect the socioemotional problems, or the association would only be seen in samples with higher levels of socioemotional problems. On the other hand, at 8 months of age, attention bias for fear may relate differently to socioemotional problems than it has later during development. Attention bias for fearful faces versus happy and neutral faces measured using the overlap task is normative at 8 months and emerges between 5 and 7 months of age (Peltola et al., 2009; Yrttiaho et al., 2014), and this relative attentional preference for fearful faces over neutral and happy faces starts to decline by 2 years of age (Kataja et al., 2022; Leppänen et al., 2018). This may imply that bias in attentional disengagement from fearful faces measured with the overlap task at 7–8 months of age plays a specific role in infant development.

Altogether, this may indicate that the associations between social-emotional attention biases and other aspects of social-emotional functioning are age-dependent. Thus, the results from previous studies on affect-biased attention and social-emotional functioning in older children, adolescents and adults should not be applied to infants without further studies. In addition, the developmental origins of the association between higher attentional threat or fear bias and internalizing symptoms remain unknown.

6.3 Attention to Emotional Facial Expressions at 8 Months and Socioemotional Competencies at 2 Years

In Study II, consistent with our hypothesis, a higher attention bias for fearful faces at the age of 8 months was related to better socioemotional competencies at the age of 2 years. The emotional bias in attentional disengagement was measured with eye tracking and the overlap task with centrally presented emotional faces and lateral distractors. The socioemotional competencies were measured with the BITSEA questionnaire filled by both parents. The association remained statistically significant when the effects of infant sex and temperament and maternal age, education level and depressive symptoms were controlled, but the effect size was very small. The hypothesis was based on a previous study demonstrating that infants' increased responsiveness to fearful faces at 7 months is related to a greater helping of others, which is an important marker of social competence at 14 months (Grossmann et al., 2018).

Based on previous findings about affect-biased attention in older children and adults, we made hypotheses that higher attention bias for fearful faces would be also related to higher amount of socioemotional problems in Study II. However, there is evidence that this assumption is contradictory to the hypothesis of the association between higher attention bias for fearful faces and better socioemotional competencies, as socioemotional problems and competencies negatively correlate during toddlerhood (Briggs-Gowan et al., 2004). In line with these previous finding, only one of the hypotheses was supported, as we found no association between affect-biased attention and socioemotional problems.

The present and the previous findings indicate that attention bias for fearful faces at 7–8 months of age may be an early precursor of prosocial behaviors. Theories on ethical behaviors and altruism emphasize the significance of detecting and reacting to fearful faces that signals fear in others (Marsh, 2016a; Pfaff et al., 2008). Moreover, as BITSEA covers both social and emotional aspects of child behaviors, our results indicate that attention bias for fearful faces is related not only to social aspects development but also to emotional aspects of development during toddlerhood.

6.4 Attention to Emotional Facial Expressions and Maternal Caregiving Behaviors at 8 Months

In Study III, the main finding was that higher maternal EA in the mother–infant interaction was related to infants' increased attention toward fearful faces. In the analyses, maternal age, education and depressive as well as anxiety symptoms and the infant sex were controlled. This finding was in line with previous studies showing that the quality of maternal caregiving behaviors is closely linked with a child's emotion processing (Garvin et al., 2012; Peltola et al., 2015, 2020; Taylor-Colls & Fearon, 2015). Adopting the idea of affect-biased attention being a form of self-regulation (Todd et al., 2012), this finding is also in line with previous experimental studies showing an association between the quality of maternal caregiving behaviors and especially emotional aspects of those behaviors and child cognitive as well as emotional self-regulation (Bridgett et al., 2015; Dix, 1991; Samdan et al., 2020). In a previous study by Kammermeier et al. (2022), the subscales of maternal EA, that were sensitivity and non-intrusiveness, were related to attention to happy and sad facial expressions, but the association between maternal EA and attention to fearful faces were not detected. There are several explanations for the discrepancy between the results of the previous and the present study. In Study III, the infants were 8 months old, and the children were a bit older, at 12 and 24 months in the study by Kammermeier et al. (2022). Also, in the previous study, biases in sustained attention were explored, whereas in Study III, bias in attentional disengagement was measured. However, both studies demonstrate the link between maternal EA and a child's affect-biased attention.

One possible explanation for this association between higher maternal EA and an infant's increased attention toward fearful faces is that maternal EA has influenced the development of an infant's affect-biased attention. This is possible, as the control of attention is one of the first forms of self-regulation during the early postnatal period (Posner et al., 2014; Rothbart et al., 2011), and emotional aspects of caregiving behaviors connects to a child's cognitive and emotional self-regulation in experimental studies (Bridgett et al., 2015; Dix, 1991; Samdan et al., 2020). The implications of this finding are related to the significance of the higher fear bias for child development. Higher attention to fear or threat may heighten the risk of later anxiety symptoms, as this association and possible causal relation exists in older children and adults (Bar-Haim et al., 2007; Dudeney et al., 2015; Hakamata et al., 2010; Mogg & Bradley, 2018; Van Bockstaele et al., 2014). On the other hand, an increased attention to fearful faces may be an adaptive alteration in emotional attention in an environment, where maternal EA is lower and may include less sensitive, less structuring and hostile and intrusive features.

The association between the quality of maternal caregiving behaviors and attention bias for fear can also be seen as a part of a larger question about intergenerational transmission of anxiety-related information processing. A theoretical model proposed by Creswell et al. (2010) first emphasized the role that threat interpretations plays in intergenerational transmission of anxiety. According to the model, statistically significant associations would be found between: (1) parent's and children's threat-related cognitive biases, (2) parents' threat-related biases in their environment and their children's environment, (3) parent's threat-related cognitive biases and parenting behaviors that increase anxiety risk of their children and (4) parenting behaviors and the child's threat-related biases. In the original model, cognitive biases included threat interpretations. Parenting behaviors, in turn, included modeling of fear and verbal threat information transmission. Aktar (2022) updated the original model. Aktar added the construct of attention bias towards threat to cognitive threat biases. In addition, Aktar added autonomy-granting parenting constructs, such as overinvolvement and overcontrol, to parenting behaviors. The construct of EA includes autonomy-granting parenting behaviors especially in the subscales of structuring and non-intrusiveness. Thus, the findings of Study III support the fourth aspect of the updated model, which is the association between parenting behaviors and a child's threat-related attention biases. The mechanisms of intergenerational transmission of anxiety are an important topic for future studies. New knowledge will further the understanding how children at risk for anxiety can benefit from interventions targeted to their parents.

6.5 General Attention Bias for Faces at 8 Months and Social-Emotional Functioning

Interestingly, no evidence for an association between general attention bias for faces at 8 months of age and social-emotional functioning was found in Studies I–III. In Studies I–III, a clear face bias (i.e., attention bias for neutral and happy faces versus a scrambled face control stimulus) was found, but individual variance in it was not related to early regulatory problems at 3 months of age, socioemotional problems or competencies at 2 years of age or maternal EA at 8 months of age. In addition, in Study IV, we found a clear attention-orienting bias for faces (i.e., attention bias for neutral faces over a scrambled face control stimulus) among 2.5- and 5-year-olds, but a face bias in sustained attention only among 2.5-year-olds but not among 5-year-olds. According to previous studies, newborn infants show attentional preferences for faces already during the time when their visual systems are immature and attention-control capacities are limited. This implies that face preference plays an important role during early development (Johnson et al., 2015; Posner et al., 2014; Reynolds & Roth, 2018). In addition, attention to faces may provide a foundation for social interaction and, later, for social-emotional development (Klin et al., 2015; Morales, Fu, et al., 2016; Reynolds & Roth, 2018). Therefore, it may have a connection, for example, to the mother–infant interaction and to the development of social competence. However, at 8 months of age, individual differences in the general attention bias for faces may not relate to social-emotional functioning but rather to differences in attention to more fine-grained features of faces such as in attention to the emotional content of the facial expressions or to specific parts of the faces, for example, the eyes or the mouth.

Our results are in contradiction with some previous studies on attention bias for faces and social-emotional functioning during early childhood. In previous studies, an increased general attention bias for faces during infancy has been related to more frequent helping-type behaviors observed in a laboratory setting and to a lower amount of callous-unemotional traits as well as to increased altruistic behaviors later during childhood (Bedford et al., 2015; Peltola et al., 2018; Rajhans et al., 2016). These findings seem to be in contradiction to the finding of Study II that found no association between the general attention bias for faces and socioemotional competencies. The explanation for the inconsistency in the results with Study II might be that the competencies scale of BITSEA contains more broadly the aspects of social-emotional functioning, including positive emotionality in addition to prosocial behavior. Therefore, it is related to the variance in bias regarding emotional information of the facial expressions. On the other hand, helping responses observed in the laboratory or callous-unemotional traits reflect more specific problems in social skills regarding empathy, remorse and the ability to relate to others' distress (Marsh, 2019). In addition, using a more natural non-face stimuli (e.g., toys or furniture) may lead to different results. The findings of the present study imply that, in studies on infants' face-related attention biases, not only a general attention bias for faces but also attention biases for emotional facial expressions should be studied.

6.6 The Changes in Emotional Attention Biases Between 2.5 and 5 Years

In Study IV, we investigated the developmental change in attention-orienting bias and bias in sustained attention for happy, fearful, angry and sad faces from 2.5 to 5 years. The task measured different subcomponents of attention, such as exogenous attention when the trial started, and the participant reacted to the appearing stimuli and more endogenous attention when they were freely looking at them when the pictures stayed still for 4000 ms. Attention-orienting variables reflect attentional engagement at the beginning of the task, while variables of sustained attention reflect gaze behaviors across the trial. Regarding attention orienting, our main findings demonstrated biases for happy and fearful faces at 2.5 and 5 years and also for sad faces at 5 years of age. That is, the probability of first looking at these emotional faces was higher compared to the neutral face. Regarding sustained attention, both

2.5- and 5-year-old children demonstrated a bias for happy, fearful, sad and angry faces versus neutral faces. In other words, these faces tended to maintain the children's attention in a free-viewing situation. In both age groups, the bias in sustained attention for fearful faces was highest. Our results also showed a statistically significant change in biases in sustained attention between 2.5 and 5 years, as all biases in sustained attention for happy, fearful, sad and angry faces increased between 2.5 and 5 years.

An attention bias for happy versus neutral faces exists among children 3–5 years old in studies using the free viewing of paired pictures (Dodd et al., 2020; Lagattuta & Kramer, 2017), the dot-probe task (Burris et al., 2017) and the overlap task (Peltola et al., 2018). However, some previous studies did not find this bias (Morales, Brown, et al., 2017; Nakagawa & Sukigara, 2012; Pérez-Edgar et al., 2011). There are also contradictory results regarding bias in sustained attention for angry faces found in Study IV, as Dodd et al. (2020) did not find this bias among children at 3–4 years old. In Study IV, we did not find an attention-orienting bias for angry faces. This finding was in line with Perez-Edgar et al. (2011) but in contradiction with findings by Burris et al. (2017). Attention bias for a fearful face is in line with the findings from previous studies using the overlap task (Nakagawa & Sukigara, 2012; Peltola et al., 2018). The strength of Study IV is a large sample size (*n* = 367–477) compared to the sample sizes of the previous studies (*n* = 26–187).

Taken together, the results from the present and previous studies, the highest attention bias seems to vary between different age groups. According to a previous study by Farroni et al (2007), attention bias for happy faces is higher than for fearful faces right after birth. However, as this is a single study, this should be interpreted with caution. There are several studies using the face-distractor overlap task at 7–8 months of age showing a clear attention bias for fearful faces over neutral and happy faces (Kataja, Karlsson, et al., 2020; Nakagawa & Sukigara, 2012; Peltola et al., 2008, 2018). In previous studies using the overlap task, relative attentional preference for fearful faces over neutral and happy faces decline between 7 months and 2 years (Peltola et al., 2018) and between 8 months and 5 years (Kataja et al., 2022). Conversely, in Study IV when free viewing of paired pictures was used, two findings indicate that attention bias for fearful faces does not decline between 2.5 and 5 years. First, a bias in sustained attention for fearful faces was highest of all attention biases both at 2.5 and at 5 years. Second, the attention bias for fearful faces increased during the follow-up.

An important new finding is that bias in sustained attention for fearful and angry faces, which indicate threat, increased between 2.5 and 5 years. Interestingly, attention-orienting bias for angry faces was not found at 2.5 or 5 years. In previous studies, attention-orienting bias for threat relates to social withdrawal, which was used as a developmentally appropriate marker of a risk for clinical anxiety in children as young as 5 years (Pérez-Edgar et al., 2011). In addition, an association between a higher threat bias in attention-orienting and anxiety symptoms exists in many studies in children older than 7 years (Dudeney et al., 2015). When attention biases are studied during early development, it important to consider that the level of attention biases may be age specific, and our results suggest that the tendency is that attention biases especially in sustained attention increase when the children grow older.

6.7 Concluding Remarks on the Attention Bias for Fearful Faces During Early Development

Studies I–IV demonstrated a clear attention bias for fearful faces at a group level at 8 months, 2.5 years and 5 years of age in attention orienting. Attention-orienting bias for fearful faces at 7–8 months has been demonstrated in many previous studies (Kataja, Karlsson, et al., 2020; Leppänen et al., 2018; Nakagawa & Sukigara, 2012; Peltola et al., 2008; Pyykkö et al., 2018). The samples of Studies I–III overlapped. In the findings of the Studies presented here, individual variance in this well-established, attention-orienting bias for fearful faces at 8 months of age is related to other aspects of a child's social-emotional development.

Four models are proposed for how affect-biased attention develops during childhood and how the association between affect-biased attention and anxiety symptoms emerges. Our results from Study IV demonstrated that attention biases for emotional faces heightened in the free viewing of paired pictures between 2.5 years and 5 years. These results are in contradiction with the first model described by Field and Lester (2010), which is the integral bias model that assumes that attention biases do not change during development. They are also in contradiction with the second model, the moderation model, that assumes that the attention biases decrease during development (Field & Lester, 2010). Instead, our results from Study IV support the third model, the acquisition model, which assumes that attention biases emerge during the development linked with cognitive, emotional and social development (Field & Lester, 2010). In addition, Studies I and II demonstrated a connection between affect-biased attention and child's emotional and social development, as increased attention toward fearful faces was linked with lower RPs at 3 months and higher socioemotional competencies at 2 years.

Finally, the results from Studies I–IV are in line with the fourth model that was briefly mentioned by Field and Lester as the hybrid model and is described in more detail by Morales, Fu, et al. (2016). The hybrid model proposes that innate attention biases are based on individual factors, and those biases are moderated by factors intrinsic and extrinsic to the child during later development. Moreover, the hybrid model emphasizes the reciprocal connections between affect-biased attention and social-emotional functioning. The findings of Studies I–III support this hypothesis, as they showed an association between affect-biased attention and factors intrinsic to the child, i.e., RP and socioemotional competencies as well as factors extrinsic to the child, i.e., maternal EA. In addition, Study IV, which was the follow-up study of attention biases for happy, fearful, angry and sad faces, showed a statistically significant change in the attention biases between 2.5 and 5 years at the group level and low individual stability suggesting that there might be both age-typical changes or maturation in attention biases and the biases might be malleable to other social-emotional factors influencing the current level of biases. However, the findings are associative and do not solve the questions of causality. Thus, the possible moderative role of factors intrinsic and extrinsic to the child in the development of affect-biased attention remains for exploration in future studies. To explore bidirectional associations, large longitudinal datasets are needed.

The early development of the connection between affect-biased attention and psychopathology is relevant especially in terms of interventions. If the integral bias model would have been supported and emotional attention biases would have been innate and stable during development, interventions could have been targeted to affect-biased attention as early as possible. If the moderation model would have been supported and attention biases would have decreased during development, the interventions should have enhanced this decrease. However, taken together from previous literature and findings from the present study, the development of affect-biased attention seems to have reciprocal connections to social-emotional functioning and factors intrinsic and extrinsic to the child. This implies that these possibly complex associations need to be well studied and understood before any interventions are developed, such that the interventions do not change the biases that are crucial for the development or adaptive in certain environments.

Little is known about the significance of increased attention toward fearful faces at 8 months of age regarding other aspects of child development. There are at least two interpretation frameworks for increased attention toward threat and fear. First, according to the theories adopting a clinically-oriented framework, heightened attention to signs of threat and fear is a maladaptive trait, as it relates 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). In Study II, increased attention toward fearful faces was associated with lower maternal EA, which is also shown to be related to adverse outcomes, in, for example, a child's emotion regulation and emotional understanding during toddlerhood and preschool years (Biringen et al., 2014; Garvin et al., 2012). This finding seems to be in line with this clinically-oriented framework connecting increased attention to fear and exposure to less optimal quality of parenting behaviors. However, in Study I, a lower attention bias for fearful faces was related to behavioral regulatory problems, and this seems to be in contradiction with the clinically-oriented framework. In addition, in Study II, we did not find an association between an increased attention toward fearful faces at 8 months of age and socioemotional problems at 2 years. Interestingly, regarding fear bias at 8 months of age, the association that is in line with this clinically-oriented framework includes factors extrinsic to the child, namely the quality of maternal caregiving behaviors in Study II. Furthermore, the associations that do not support this framework are related to factors intrinsic to the child, which are behavioral regulatory problems and socioemotional problems and competencies. However, these are only a few studies, and more studies are needed to make stronger conclusions.

Taking another perspective that fits with the clinically-oriented framework, Callaghan and Tottenham (2016) also combine adverse social factors and higher responses to signs of threat in their model of the neuro-environmental loop of plasticity. According to the model, parents act to buffer their child's emotional reactivity, and the brain needs this buffering when the emotion regulation systems are developing. Parental absence or unavailability during the sensitive period of emotion regulation systems leads to heightened amygdala reactivity and emotional reactivity. Based on this model, it is possible that less optimal quality of maternal caregiving behaviors sensitizes an infant's emotion processing system for signals of fear, and, thus, a lower maternal EA is related to increased attention toward fearful faces.

Second, an evolutionary-oriented framework consisting of models that are more recent hypothesizes that increased attention to signs of fear is an adaptive trait in social contexts (Grossmann, 2022). It states that 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, 2016a, 2019). The results from Study II are in line with this theoretical framework, as it showed that increased attention toward fearful faces at 8 months is related to better socioemotional competencies at 2 years.

6.8 Reliability and Validity of the Measures

There is an ongoing discussion about the reliability of the tasks measuring visual search and affect-biased attention (Fu & Pérez-Edgar, 2019; Hessels et al., 2016; Kappenman et al., 2014; Kruijt et al., 2019; Machulska et al., 2022; Rodenbauch et al., 2016; Schmukle, 2005). It has been argued that visual search and attention-bias measures, such as those derived from the dot-probe task, show poor internal consistency and test-retest reliability (Cousijn et al., 2017; Rodenbauch et al., 2016; Schmukle, 2005). Detecting associations at the individual level requires a higher level of reliability than to detect differences between groups, thus, the measures of affect-biased attention are more reliable measures at a group level (Cousijn et al., 2017; Rodenbauch et al., 2016; Schmukle, 2005). Thus, the results from experimental study designs are not compromised because of poor internal consistency, but the correlational relations between affect-biased attention and other individual factors are poorly replicable (Hedge et al., 2018). According to a study by Kataja et al. (2023), disengagements probabilities for fearful face and fear bias have poor internal consistency in the whole FinnBrain sample, the subsamples of which were used in Studies I–III. Thus, more studies on the connection between, for example, affect-biased attention and socioemotional problems with more reliable measures of affect-biased attention are needed. In Study IV, emotional attention biases for happy, fearful, angry and sad faces compared with neutral faces are studied at the group level, and the experimental measures can be seen as reliable for this purpose. However, the poor internal consistency compromises the reliability of the correlational analyses between 2.5 and 5 years in Study IV, and the results should thus be interpreted with caution.

There are possible solutions to the reliability problem. The overlap task comprised 48 trials and, on the average, 8.9–9.29 valid trails per condition were used in the analyses. The face pair task included 36 trails and the average number of valid trials per condition was between 4.81 and 5.55 for the emotional face conditions. The number of trials was reduced as much as possible, as the eye-tracking measurement was conducted during a study visit including many other measures with young participants. One possible solution to this problem may be to increase the number of trials per condition as was done, for example, in Study IV, where the reliability estimates across all 36 trials were at acceptable levels, while the reliability measures calculated separately for all conditions with only 6 trials showed poor or unacceptable internal consistency. However, a higher number of trials did not solve the problem of poor internal consistency in previous studies among children (Dodd et al., 2020). In addition, a change in children's responses to stimuli over the course of the task is reported in Kataja, Karlsson et al. (2020) concerning the overlap task and in Study IV concerning the face-pair task. They demonstrate that a child's responses to stimuli change over the course of time not just reflecting a decreased interest in the task, but, in a complex way, by which the gaze behavior in one trial may be affected by the previous trials. It would be possible to increase the number of trials per condition but to reduce the number of conditions. For example, the study may focus on attention to fearful faces, as previous and present studies highlight its significance at 7–8 months. However, in Studies I and II, we focused on face and fear bias in which the disengagement probabilities for fearful faces were compared to average disengagement probabilities for other facial expressions, that were neutral and happy faces. With these stimuli, we were able to state that the findings were related to emotional content of the facial expressions rather than to the overall tendency to disengage attention from faces. Thus, other conditions than fearful faces were also needed.

Another solution to this reliability problem may be to combine information from multiple measures of affect-biased attention at multiple levels of analyses that increases the reliability at an individual level (Rodenbauch et al., 2016; Vallorani et al., 2021). Some recent studies have combined results from different attention tasks. Latent profile analyses across several tasks have revealed individual profiles including both attention bias towards targets and away from targets (Vallorani et al., 2021). This implies that, instead of focusing on only attention bias toward the threat or away from threat, preferably the focus is on individual attention profiles consisting of attention both towards and away from salient stimuli and both positive and negative valence (Vallorani et al., 2021). In conclusion, when using the overlap task and free viewing of paired emotional face pictures with children, reliability remains a concern, and in large sample sizes, comparisons at the group level and a combination of several attention tasks may be needed.

The comparison of the levels of fear bias among different studies may not be practically feasible, as the procedures vary between studies and even small changes in study protocols may impact the attention measures (Kataja, Karlsson, et al., 2020; Leppänen et al., 2018; Nakagawa & Sukigara, 2012; Peltola et al., 2008). This implies that when comparing the mean levels of fear bias in two groups, as, for example, in Study I in the RP and no-RP groups, it is not possible to estimate how these relate to normative levels of fear bias in an infant population. Future studies need to balance between the benefits of using replicating methodology from previous studies and the benefits of adjusting the task for the needs of the current study.

6.9 Strengths and Limitations of the Studies

Some strengths and limitations of the present study are related to preconditions of a large cohort study. To date, the number of participants in eye-tracking studies at 8 months, 2.5 and 5 years is among the largest samples published. In addition, this study asks study questions on child development with a longitudinal study design. Nevertheless, the attrition rate for Studies I–III was relatively high. The whole eye-tracking sample of the overlap task comprised 363 infants, but only a sample of 176 infants in Study I and 242 infants in Study II was used mostly due to the missing questionnaire data. Also, in Study III, the sample was reduced to 149 infants, because the mother–infant interaction was added to the study protocol in the middle of the data collection. In Study IV, only 216 children participated in both the 2.5- and 5-year measurement of the free viewing of paired pictures.

One of the benefits of a large cohort study is that many questions can be answered with the same collected data, as all data collection is done in cooperation with a multiprofessional group, and several aspects of development are covered in the whole data. For example, in Studies I–III, many possible confounding factors, such as a child's temperament or parental psychological distress, were available as data and their effect could be controlled in the analyses. Unfortunately, when many different measures are used, every single measure should require as little effort as possible from the participants. Thus, short versions of the questionnaires for behavioral regulatory problems and socioemotional problems and competencies were used, which may be considered a shortcoming. Behavioral regulatory problems could have been measured with more detailed questionnaires or interviews and socioemotional problems and competencies with a more extensive version of BITSEA, that is, the ITSEA. However, some of the domains in the present study were measured with experimental or observational methods that require more effort. They included the main domain, eye tracking of attention to emotional faces used in all Studies I–IV and the observations of the quality of maternal caregiving behaviors in Study III.

One of the strengths of the present study is that it managed to collect relatively large amounts of data from young children. The data from the free viewing of paired pictures in Study IV provides rare follow-up data and it covers also the less studied toddler years. Most likely, previous toddler data are few because of the challenges in cooperation. Also, in our sample, 53 children refused to participate at the 2.5-year visit, while only 8 children refused at the age of 5 years. Luckily, because of the large sample, we still managed to conduct 367 measurements successfully. In addition, algorithms developed to improve the quality of the eye-tracking data of poorly cooperating participants were used (Hessels et al., 2017; Leppänen et al., 2015).

Some of the limitations of the present study are related to decisions made concerning the eye-tracking measurement of affect-biased attention. One clear limitation in this study is the ecological validity of the emotional face tasks containing still pictures of posed emotional facial expressions. Static face stimuli are different from emotional expressions observed in real life, which compromise validity and generalizability of the results. In the future, the possibilities of mobile eye-tracking recordings during natural social interaction should be utilized (Fu & Pérez-Edgar, 2019). For example, typical attention patterns in children with high temperamental behavioral inhibition was observed both in a traditional dot-probe task with happy and angry faces paired with neutral faces and in mobile eye-tracking recordings (Fu, Nelson, et al., 2019). Mobile eye-tracking recordings can study the interaction between attention patterns and social behaviors in naturalistic environments (Fu & Pérez-Edgar, 2019). A combination of well-controlled tasks in laboratory settings and naturalistic mobile recordings during the live social interaction will further the knowledge of attention patterns and social-emotional functioning. Another limitation is that the teeth of the actress were seen only in the happy and fearful pictures. Previous studies have shown that teeth attract attention orienting (Blanco et al., 2017; Calvo & Nummenmaa, 2008). However, the fixation heatmaps on faces suggest that the mouth attracts children's attention also when the teeth were not visible. In addition, one possible limitation of the face pair task is that neutral faces are presented in every trial, which may cause an increased attention to other facial expressions as the participants habituate to the neutral face. However, the association between trial number and total fixation time is low indicating low habitation to neutral faces over the course of the task.

One limitation of the present study is that it only included measures of visual attention. Although attention biases manifest in all sensory modalities, the existing literature, including the present study, focuses on visual attention (Amso & Scerif, 2015). Yet, the model by Morales, Fu, et al. (2016) suggests that attention biases play a central domain-general role in a child's social-emotional development. An interesting topic for future research is to explore if the same associations can be found using measures targeted to attention biases in other sensory modalities, for example, in auditory attention.

A strength of this study is that both parents' reports of early regulatory problems and socioemotional problems and competencies were used when available. However, a limitation is that we did not include paternal EA when studying caregiving behaviors. Studies of the impact of the fathers' mental health and the father–infant interaction are rare, although there is strong evidence demonstrating that fathers play a crucial role in child development (Aktar & Bögels, 2017; Möller et al., 2016).

One limitation of the study is relatively large number of missing data. There is no major differences between the children included in analyses and children dropping out of the analyses because of missing parental questionnaires or dropping out of the follow-up study visit. However, as the long questionnaires and relatively frequent study visits require active participation from the families, it is possible that the study sample does not represent well low resourced families who did not participate at all. The findings from the Studies I–IV can most likely be generalized to young children with European origin besides the missing data, but replicating these studies in special populations would provide more insight on the topic. Similar developmental patterns in affect-biased attention and similar associations between affect-biased attention and social-emotional functioning can be found also among children from other cultures. For example, the age-typical attention bias for fearful faces at 8 months of age exists in Africa (Pyykkö et al., 2018), in Asia (Nakagawa & Sukigara, 2012), in North America (Leppänen et al., 2018) as well as in Europe (Peltola et al., 2008). The generalizability of our results will be an interesting topic for future research to address. In addition, the findings concern the general population, and, for example, the levels of socioemotional problems are low in Study II and the quality of maternal caregiving behaviors is high in Study III. Future research should investigate these connections in high-risk groups.

In our opinion, the mixed-effects logistic regression was the best statistical analysis method to study, how infant regulatory problems or maternal EA are related to disengagement probabilities (yes or no). However, MELR-models provide only odd ratios that are unstandardized measures of the effect size. The missing standardized effect sizes are a limitation of the Studies I and III.

The results cannot be generalized to other types of attention measures without further investigation. For example, measures of other components of attention may result in different outcomes. Already, the early theories on the relation between attention biases and psychopathology propose that different psychopathologies may impact biases in different components of attention (Yiend, 2010). This idea may be applicable also to different aspects of social-emotional functioning. In addition, our results concern attention to emotional faces when combined with neutral faces and face-pair tasks with different emotion combinations and may lead to different findings. For example, a measure with a pair of a positive and negative faces demonstrated children's attentional preference for negative faces over positive faces (Lagattuta & Kramer, 2017), a finding that is not shown with emotional-neutral face pairs in Study IV.

6.10 Future Perspectives and Clinical Implications

The results of the present study provide new information about the early connections between affect-biased attention and social-emotional functioning during infancy and toddlerhood, and they should be considered in planning the interventions for infants on affect-biased attention. It is well established that during childhood, adolescence and adulthood threat-related attention biases are related to anxiety symptoms (Bar-Haim et al., 2007; Dudeney et al., 2015; Mogg & Bradley, 2018), and interventions exist to decrease the attention bias for threat to lower anxiety symptoms (Van Bockstaele et al., 2014). Adaptations of Attention Bias Modification Training (ABMT) for children are studied with some promising results (Hakamata et al., 2010). The goal of the ABMT is to reduce attention bias for threat with repetitive, computer-based methods targeting implicit, subcortical attention processes, and, thereby, to lower anxiety symptoms (Hakamata et al., 2010). Previously, ABMT was criticized mainly because of the problems in the reliability of the measures of attention bias for threat used in pre- and post-treatment assessments (Kruijt et al., 2019). In addition, the developmental origins of this association between attentional threat bias and anxiety symptoms remain uncertain (Field & Lester, 2010; Fu & Pérez-Edgar, 2019; Morales, Fu, et al., 2016). Now, Studies I and II failed to find a connection between a higher attention bias for fearful faces at 8 months and regulatory problems at 3 months or socioemotional problems at 2 years that both relate to internalizing problems including anxiety symptoms later during development (Briggs-Gowan et al., 2016; Hemmi et al., 2011). Conversely, a higher attention bias for fearful faces is connected to positive aspects of development such as lower levels of regulatory problems at 3 months and better socioemotional competencies at 2 years. In addition, in Study IV, attention bias toward both angry and fearful faces increased between 2.5 and 5 years during typical development. Thus, attention bias training used with older children and adults cannot be applied to young children without further studies demonstrating causal connections between affect-biased attention during infancy and later psychopathology. However, if affect-biased attention is one factor that binds a child to an adaptive or maladaptive developmental pathway, as proposed in theoretical models (Morales, Fu, et al., 2016), then the earlier an intervention takes place during development may be more effective. This raises the question, when the association between attention bias for threat and anxiety symptoms emerge during development, if not during infancy.

The results from Study I may indicate that not only regulatory problems persisting over 3 or 6 months but also regulatory problems before 3 months of age may be related to other aspects of social-emotional development, such as affect-biased attention presented here. Our results indicate that parents' worry about their infants excessive crying and problems in sleeping and feeding as early as 3 months of age, and this may provide important information that has connections to other aspects of social-emotional development later during development. The connections between early regulatory problems and affect-biased attention and internalizing and externalizing problems are important topics for future research. If children at risk for psychiatric symptoms could be identified already during infancy, possible preventive interventions could be targeted to them and their families. When the children at risk are detected, standard prevention and intervention already available can be offered. In a previous study, parents with infants with behavioral regulatory problems valued two sources of support the most: direct contact with health service professionals and digital information and guidance related to infant regulatory problems available on-line (Long et al., 2018). In future studies, more targeted interventions can be developed and studied based on the better understanding of early developmental pathways from risk factors to psychopathology.

In Studies I-III, only one measurement of affect-biased attention and one measurement of social-emotional functioning were used in the analyses. Now that the simple connections have been demonstrated, it is justified to collect longitudinal data of both affect-biased attention and social-emotional functioning and to study, what kind of developmental changes can be found in these connections.

United Nation's Sustainable Development Goals emphasize the importance of early development in the Goal 4.2 that states, "By 2030, ensure that all girls and boys have access to quality early childhood development, care and preprimary education so that they are ready for primary education." Studies presented here take part in this effort by focusing on early childhood and by exploring the early origins of the associations between affect-biased attention and social-emotional functioning. Studies I–IV provide new information about early connections and development. This information together with other related literature can be used for the development of better tools to detect children at risk for problems in social-emotional functioning and to develop more targeted early interventions.

7 Conclusions

The studies that comprise this thesis demonstrate the associations between individual variance in affect-biased attention and social-emotional functioning as well as the developmental change during early childhood.

We showed that behavioral regulatory problems that are excessive crying and problems in feeding and sleeping at 3 months of age are associated with lower attention bias for fearful faces versus happy and neutral faces at 8 months of age. Attention bias for fearful faces is a robust finding among 7–8-month-old infants (Kataja, Karlsson, et al., 2020; Leppänen et al., 2018; Nakagawa & Sukigara, 2012; Peltola et al., 2008) and emerges between 5 and 7 months of age (Peltola et al., 2009; Yrttiaho et al., 2014). However, the significance of the individual variance in this bias is not yet known. Persistent and multiple behavioral regulatory problems during infancy relate to internalizing and externalizing symptoms as well as ADHD later during childhood (Hemmi et al., 2011). The present study provides new information about the less studied early behavioral regulatory problems showing that they are related to processing of emotional information later during infancy.

Against our hypotheses, we did not find associations between attention bias for fearful faces at 8 months and socioemotional problems measured with the BITSEA at 2 years. Socioemotional problems include internalizing and externalizing symptoms among other symptoms, and, later during childhood, anxiety symptoms include internalizing symptoms (Briggs-Gowan et al., 2016). Thus, socioemotional problems were considered as early markers of anxiety symptoms that are connected to attention bias for threat among children older than 7 years (Dudeney et al., 2015) and among adults (Bar-Haim et al., 2007; Mogg & Bradley, 2018). There are some previous findings on associations between attention bias for threat and other possible early risk markers of anxiety symptoms, for example, temperamental behavioral inhibition in infants and toddlers (Pérez-Edgar et al., 2017) and social withdrawal in children at 5 years (Pérez-Edgar et al., 2011). However, our results suggest that this association should be explored more before any interventions are targeted to attention biases during infancy or toddlerhood.

Instead of socioemotional problems, increased attention bias for fearful faces at 8 months was related to better socioemotional competencies also measured with the

BITSEA at 2 years. This finding is in line with previous findings on heightened attention to fear and prosocial behaviors (Grossman et al., 2018). This finding is also in line with some theoretical models proposing that detecting fear in others promotes altruism and cooperative behaviors (Grossmann, 2022; Marsh, 2016a, 2019). This may imply that higher attention bias for fearful faces at 8 months of age has positive developmental outcomes.

We also found that a lower quality of maternal caregiving behaviors connects to increased attention to fearful faces at 8 months of age. More specifically, maternal caregiving behaviors were measured with Emotional Availability Scales (Biringen et al., 1998) that include four maternal dimensions: sensitivity, structuring, non-hostility and non-intrusiveness. Again, the significance of the increased attention to fearful face in child development remains for future studies to address.

Finally, the follow-up study using free viewing of paired face pictures demonstrated an attention-orienting bias for happy and fearful faces compared with neutral faces at 2.5 and 5 years and for sad faces at 5 years. In addition, it demonstrated bias in sustained attention for happy, fearful, angry and sad faces compared with neutral faces at 2.5 and 5 years. In addition, all attention biases in sustained attention increased between 2.5 and 5 years. This implies that attention biases in sustained attention relates to a both negative and positive emotion increase during early childhood.

Affect-biased attention is widely studied in relation to psychopathology in children and adolescents older than 7 years and in adults (Bar-Haim et al., 2007; Dudeney et al., 2015; Mogg & Bradley, 2018). However, the developmental pathways leading to those associations are not yet known (Field & Lester, 2010; Morales, Fu, et al., 2016). The presented studies suggest that the association between affect-biased attention and social-emotional functioning may be different during early childhood than later in childhood and in adulthood. Eye tracking of young children's attention to emotional faces seems to be a promising method for studying early development of emotion processing. However, the ecological validity of the tasks and the reliability of the measures at individual level need to be developed further. Future studies on affect-biased attention and other aspects of a child's social-emotional functioning are recommended.

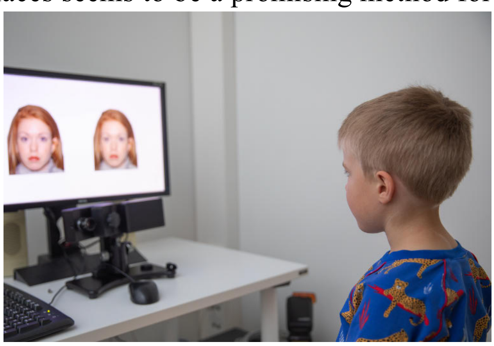

Figure 11. A participant at the 5-year study visit.

Abbreviations

ABMT	Attention Bias Modification Training
ADHD	Attention-deficit hyperactivity disorder
BITSEA	Brief Infant Toddler Social Emotional Assessment
CogBIAS	Cognitive Bias Hypothesis
DC 0–3	Diagnostic Classification of Mental Health and Developmental Disorders of Infancy and Early Childhood
DP	Disengagement Probability
EA	Emotional Availability
EAS	Emotional Availability Scales
EEG	Electroencephalogram
EPDS	Edinburgh Postnatal Depression Scale
I2MC	Identification by Two-means Clustering
IBQ-R	Infant Behavior Questionnaire Short Form Revised
MERL	Mixed Effects Logistic Regression
NC	Negative Central
NEG	Temperamental Negative Affectivity
PRAQ-R2	Pregnancy-related Anxiety Questionnaire-Revised 2
RP	Regulatory Problems
SCL-90	Symptom Checklist-90
SUR	Temperamental Surgency/Extraversion
TFT	Total Fixation Time
TNS	Trial Number Spline Term

List of References

Aatsinki, A.-K., Kataja, E.-L., Munukka, E., Lahti, L., Keskitalo, A., Korja, R., Nolvi, S., Häikiö, T., Tarro, S., Karlsson, H., & Karlsson, L. (2022). Infant fecal microbiota composition and attention to emotional faces. *Emotion, 22,* 1159–1170. https://doi.org/10.1037/emo0000924

Achenbach, T. M. (1966). The classification of children’s psychiatric symptoms: a factor-analytic study. *Psychological Monographs*, *80*(7), 1–37. https://doi.org/10.1037/h0093906

Aktar, E. (2022). Intergenerational transmission of anxious information processing biases: An updated conceptual model. *Clinical Child and Family Psychology Review, 25(1),* 182–203. https://doi.org/10.1007/s10567-022-00390-8

Aktar, E., & Bögels, S. M. (2017). Exposure to parents’ negative emotions as a developmental pathway to the family aggregation of depression and anxiety in the first year of life. *Clinical Child and Family Psychology Review*, *20*(4), 369–390. https://doi.org/10.1007/s10567-017-0240-7

Aktar, E., Nimphy, C. A., Kret, M. E., Pérez-Edgar, K., Maartje, E., & Bögels, S. M. (2022). Attention biases to threat in infants and parents: Links to parental and infant anxiety dispositions. *Research on Child and Adolescent Psychopathology, 50,* 387–402. https://doi.org/10.1007/s10802-021-00848-3

Alakortes, J., Fyrstén, J., Carter, A. S., Moilanen, I. K., & Ebeling, H. E. (2015). Finnish mothers’ and fathers’ reports of their boys and girls by using the Brief Infant-Toddler Social and Emotional Assessment (BITSEA). *Infant Behavior and Development*, *39*, 136–147. https://doi.org/10.1016/j.infbeh.2015.02.016

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

Amso, D., & Scerif, G. (2015). The attentive brain: insights from developmental cognitive neuroscience. *Nature Reviews Neuroscience*, *16*(10), 606–619. https://doi.org/10.1038/nrn4025.

Aslin, R. N., & Salapatek, P. (1975). Saccadic localization of visual targets by the very young human infant. *Perception & Psychophysics*, *17*(3), 293–302.

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*(1). https://doi.org/10.18637/jss.v067.i01

Bäuml, J. G., Baumann, N., Avram, M., Bratec, S. M., Breeman, L., Berndt, M., … Sorg, C. (2019). The default mode network mediates the impact of infant regulatory problems on adult avoidant personality traits. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *4*(4), 333–342. https://doi.org/10.1016/j.bpsc.2018.11.005

Beck, A. T. (1976). *Cognitive therapy and the emotional disorders.* New York: International Universities Press.

Bedford, R., Pickles, A., Sharp, H., Wright, N., & Hill, J. (2015). Reduced face preference in infancy: A developmental precursor to callous-unemotional traits? *Biological Psychiatry*, *78*(2), 144–150. https://doi.org/10.1016/j.biopsych.2014.09.022

Belsky, J., Bakermans-Kranenburg, M. J., & Van Ijzendoorn, M. H. (2007). For better and for worse: Differential susceptibility to environmental influences. *Current Directions in Psychological Science*, *16*(6), 300–304. https://doi.org/10.1111/j.1467-8721.2007.00525.x

Belsky, J., & Fearon, P. R. M. (2002). Early attachment security, subsequent maternal sensitivity, and later child development: Does continuity in development depend upon continuity of caregiving? *Attachment & Human Development*, *4*(3), 361–387. https://doi.org/10.1080/1461673021016726

Belsky, J., & Pluess, M. (2009). Beyond diathesis stress: differential susceptibility to environmental influences. *Psychological Bulletin*, *135*(6), 885–908. https://doi.org/10.1037/a001737

Bertenthal, B. I., & Campos, J. J. (1984). A reexamination of fear and its determinants on the visual cliff. *Psychophysiology*, *21*(4), 413–417.

Bethlehem, R. A. I., Seidlitz, J., White, S. R., Vogel, J. W., Anderson, K. M., Adamson, C., … Alexander-Bloch, A. F. (2022). Brain charts for the human lifespan. *Nature*, *604*(February). https://doi.org/10.1038/s41586-022-04554-y

Bierstedt, L., Reider, L. B., Burris, J. L., Vallorani, A., Gunther, K. E., Buss, K. A., … LoBue, V. (2022). Bi-directional relations between attention and social fear across the first two years of life. *Infant Behavior and Development*, *69*(June), 1–17. https://doi.org/10.1016/j.infbeh.2022.101750

Bilgin, A., Baumann, N., Jaekel, J., Breeman, L. D., Bartmann, P., Avram, M., & Wolke, D. (2020). Early crying, sleeping, and feeding problems and trajectories of attention problems from childhood to adulthood. *Child Development*, *91*(1). https://doi.org/10.1111/cdev.13155

Biringen, Z. (2008). *The EA Professionals and Parent Curricula.* Available at http://www.emotionalavailability.com.

Biringen, Z., Derscheid, D., Vliegen, N., Closson, L., & Easterbrooks, M. A. (2014). Emotional availability (EA): Theoretical background, empirical research using the EA Scales, and clinical applications. *Developmental Review*, *34*(2), 114–167. https://doi.org/10.1016/j.dr.2014.01.002

Biringen, Z., Robinson, J., & Emde, R.N. (1998). *The Emotional Availability Scales (3rd ed.)*, unpublished manuscript, Department of Human Development & Family Studies, Colorado State University, Fort Collins, CO.

Blanco, I., Serrano-Pedraza, I., & Vázquez, C. (2017). Don't look at my teeth when I smile: Teeth visibility in smiling faces affects emotionality ratings and gaze patterns. *Emotion*, *17*(4), 640–647. https://doi.org/10.1037/emo0000260

Bowlby, J. (1969). *Attachment and Loss, Vol. 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*(3), 602–654. https://doi.org/10.1037/a0038662

Briggs-Gowan, M. J., & Carter, A. S. (1998). Preliminary acceptability and psychometrics of the infant-toddler social and emotional assessment (ITSEA): A new adult-report questionnaire. *Infant Mental Health Journal*, *19*(4), 422–445. https://doi.org/10.1002/(SICI)1097-0355(199824)19:4<422::AID-IMHJ5>3.0.CO;2-U

Briggs-Gowan, M. J., Carter, A. S., Bosson-Heenan, J., Guyer, A. E., & Horwitz, S. M. (2006). Are infant-toddler social-emotional and behavioral problems transient? *Journal of the American Academy of Child & Adolescent Psychiatry*, *45*(7), 849–858. https://doi.org/10.1097/01.chi.0000220849.48650.59

Briggs-Gowan, M. J., Carter, A. S., Irwin, J. R., Wachtel, K., & Cicchetti, D. V. (2004). The Brief infant-toddler social and emotional assessment: Screening for social-emotional problems and delays in competence. *Journal of Pediatric Psychology*, *29*(2), 143–155. https://doi.org/10.1093/jpepsy/jsh017

Briggs-Gowan, M. J., Godoy, L., Heberle, A., & Carter, A. S. (2016). Assessment of psychopathology in young children. In D. Cicchetti (Ed.), *Developmental Psychopathology, Theory and Method* (pp. 1–46). Hoboken, New Jersey: Wiley.

Brown, H. M., McAdams, T. A., Lester, K. J., Goodman, R., Clark, D. M., & Eley, T. C. (2013). Attentional threat avoidance and familial risk are independently associated with childhood anxiety disorders. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *54*(6), 678–685. https://doi.org/10.1111/jcpp.12024

Burmeister, M., McInnis, M. G., & Zöllner, S. (2008). Psychiatric genetics: Progress amid controversy. *Nature Reviews Genetics*, *9*(7), 527–540. https://doi.org/10.1038/nrg2381

Burris, J. L., Barry-Anwar, R. A., & Rivera, S. M. (2017). An eye tracking investigation of attentional biases towards affect in young children. *Developmental Psychology*, *53*(8), 1418–1427. https://doi.org/10.1037/dev0000345

Burris, J. L., Buss, K., Lobue, V., & Field, A. P. (2019). Biased attention to threat and anxiety: On taking a developmental approach. *Journal of Experimental Psychopathology*, 1–21. https://doi.org/10.1177/2043808719860717

Callaghan, B. L., & Tottenham, N. (2016). The neuro-environmental loop of plasticity: A cross-species analysis of parental effects on emotion circuitry development following typical and adverse caregiving. *Neuropsychopharmacology*, *41*(1), 163–176. https://doi.org/10.1038/npp.2015.204

Calvo, M. G., & Nummenmaa, L. (2008). Detection of emotional faces: Salient physical features guide effective visual search. *Journal of Experimental Psychology: General*, *137*(3), 471–494. https://doi.org/10.1037/a0012771

Caspi, A., & Moffitt, T. E. (2006). Gene-environment interactions in psychiatry: Joining forces with neuroscience. *Nature Reviews Neuroscience*, *7*(7), 583–590. https://doi.org/10.1038/nrn1925

Cisler, J. M., & Koster, E. H. W. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical Psychology Review*, *30*(2), 203–216. https://doi.org/10.1016/j.cpr.2009.11.003

Cousijn, J., Hessels, R. S., Van der Stigchel, S., & Kemner, C. (2017). Evaluation of the psychometric properties of the gap-overlap task in 10-month-old infants. *Infancy*, *22*(4), 571–579. https://doi.org/10.1111/infa.12185

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

Creswell, C., Cooper, P., & Murray, L. (2010). Intergenerational trans- mission of anxious information processing biases. In J. A. Hadwin & A. P. Field (Eds.), *Information processing biases and anxiety: A developmental perspective* (pp. 279–295). Wiley, Blackwell.

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

Crugnola, C. R., Ierardi, E., Ferro, V., Gallucci, M., Parodi, C., & Astengo, M. (2016). Mother-infant emotion regulation at three months: The role of maternal anxiety, depression and parenting stress. *Psychopathology*, *49*(4), 285–294. https://doi.org/10.1159/000446811

de Haan, M., Belsky, J., Reid, V., Volein, A., & Johnson, M. H. (2004). Maternal personality and infants' neural and visual responsivity to facial expressions of emotion. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *45*(7), 1209–1218. https://doi.org/10.1111/j.1469-7610.2004.00320.x

Denham, S. A., Wyatt, T. M., Bassett, H. H., Echeverria, D., & Knox, S. S. (2009). Assessing social-emotional development in children from a longitudinal perspective. *Journal of Epidemiology and Community Health*, *63*(SUPPL. 1). https://doi.org/10.1136/jech.2007.070797

Dix, T. (1991). The affective organization of parenting: adaptive and maladaptative processes. *Psychological Bulletin*, *110*(1), 3–25.

Dodd, H. F., Rayson, H., Ryan, Z., Bishop, C., Parsons, S., & Stuijfzand, B. (2020). Trajectories of anxiety when children start school: The role of behavioral inhibition and attention bias to angry and happy faces. *Journal of Abnormal Psychology*, *129*(7), 701–712. https://doi.org/10.1037/abn0000623

Dudeney, J., Sharpe, L., & Hunt, C. (2015). Attentional bias towards threatening stimuli in children with anxiety: A meta-analysis. *Clinical Psychology Review*, *40*(August), 66–75. https://doi.org/10.1016/j.cpr.2015.05.007

Dykas, M. J., & Cassidy, J. (2011). Attachment and the processing of social information across the life span: Theory and evidence. *Psychological Bulletin*, *137*(1), 19–46. https://doi.org/10.1037/a0021367

Emde, R. N. (1998). Early emotional development: New modes of thinking for research and intervention. *Pediatrics*, *102*(5), 1236–1243.

Eysenck, M. W. (1992). *Anxiety: The cognitive perspective.* Hove, England: Psychology Press.

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

Feldman, R., & Masalha, S. (2010). Parent-Child and Triadic Antecedents of Children's Social Competence: Cultural Specificity, Shared Process. *Developmental Psychology*, *46*(2), 455–467. https://doi.org/10.1037/a0017415

Field, A. P., & Lester, K. J. (2010). Is there room for "development" in developmental models of information processing biases to threat in children and adolescents? *Clinical Child and Family Psychology Review*, *13*(4), 315–332. https://doi.org/10.1007/s10567-010-0078-8

Field, T. M. (1981). Infant gaze aversion and heart rate during face-to-face interactions. *Infant Behavior and Development*, *4*(1), 307–315. https://doi.org/10.1016/S0163-6383(81)80032-X

Forslund, T., Peltola, M. J., & Brocki, K. C. (2020). Disorganized attachment representations , externalizing behavior problems , and socioemotional competences in early school-age. *Attachment & Human Development*, *22*(4), 448–473. https://doi.org/10.1080/14616734.2019.1664603

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*(7), 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*(March), 1657–1662. https://doi.org/10.1038/mp.2016.114

Fox, N. A., Henderson, H. A., Rubin, K. H., Calkins, S. D., & Schmidt, L. A. (2001). Continuity and discontinuity of behavioral inhibition and exuberance: Psychophysiological and behavioral influences across the first four years of life. *Child Development*, *72*(1), 1–21.

Frank, M. C., Vul, E., & Johnson, S. P. (2009). Development of infants' attention to faces during the first year. *Cognition*, *110*(2), 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*(4), 355–375. https://doi.org/10.1111/j.1532-7078.2011.00086.x

Fu, X., Nelson, E. E., Borge, M., Buss, K. A., & Pérez-Edgar, K. (2019). Stationary and ambulatory attention patterns are differentially associated with early temperamental risk for socioemotional problems: Preliminary evidence from a multimodal eye-tracking investigation. *Development and Psychopathology*, *31*, 971–988. https://doi.org/10.1017/S0954579419000427

Fu, X., & Pérez-Edgar, K. (2019). Threat-related attention bias in socioemotional development: A critical review and methodological considerations. *Developmental Review*, *51*(November 2018), 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

Garvin, M. C., Tarullo, A. R., Van Ryzin, M., & Gunnar, M. R. (2012). Postadoption parenting and socioemotional development in postinstitutionalized children. *Development and Psychopathology*, *24*(1), 35–48. https://doi.org/10.1017/S0954579411000642

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*(1), 145–158. https://doi.org/10.1080/13506280444000076

Gibb, B. E., Johnson, Ashley, L., Benas, J. S., Uhrlass, D. J., Knopik, V. S., & McGeary, J. E. (2011). Children's 5-HTTLPR genotype moderates the link between maternal criticism and attentional biases specifically for facial displays of anger. *Cognition and Emotion*, *25*(6), 1104–1120. https://doi.org/10.1080/02699931.2010.508267

Grafton, B., Visu-Petra, L., Marcuş, O., Liebregts, H., & MacLeod, C. (2016). Controlling the bias: Inhibitory attentional control moderates the association between social anxiety and selective attentional responding to negative social information in children and adolescents. *Journal of Experimental Psychopathology*, *7*(3), 423–436. https://doi.org/10.5127/jep.055916

Gross, S. (2016). Approaches to diagnosing regulatory disorders in infants. In M. Cierpka (Ed.), *Regulatory Disorders in Infants*. Cham: Springer International Publishing.

Grossmann, T. (2022). The human fear paradox: Affective origins of cooperative care. *Behavioral and Brain Sciences*, 1–43. https://doi.org/https://doi.org/10.1017/S0140525X2200067X

Grossmann, T., Missana, M., & Krol, K. M. (2018). The neurodevelopmental precursors of altruistic behavior in infancy. *PLoS Biology*, *16*(9), 1–22. https://doi.org/10.1371/journal.pbio.2005281

Gulley, L., Oppenheimer, C., & Hankin, B. (2014). Associations among negative parenting, attention bias to anger, and sosial anxiety among youth. *Developmental Psychology*, *50*(2), 577–585. https://doi.org/10.1037/a0033624

Gunther, K. E., Fu, X., MacNeill, L., Vallorani, A., Ermanni, B., & Pérez-Edgar, K. (2022). Profiles of naturalistic attentional trajectories associated with internalizing Bbhaviors in school-age children: A mobile eye tracking study. *Research on Child and Adolescent Psychopathology*, *50*(5), 637–648. https://doi.org/10.1007/s10802-021-00881-2

Hains, S. M. J., & Muir, D. W. (1996). Infant sensitivity to adult eye direction. *Child Development*, *67*, 1940–1951.

Hakamata, Y., Lissek, S., Bar-Haim, Y., Britton, J. C., Fox, N. A., Leibenluft, E., … Pine, D. S. (2010). Attention bias modification treatment: A meta-analysis toward the establishment of novel treatment for anxiety. *Biological Psychiatry*, *68*(11), 982–990. https://doi.org/10.1016/j.biopsych.2010.07.021

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

Hammer, J. L., & Marsh, A. A. (2015). Why do fearful facial expressions elicit behavioral approach? Evidence from a combined approach-avoidance implicit association test. *Emotion*, *15*(2), 223–231. https://doi.org/10.1037/emo0000054.Why

Harris, L. M., & Menzies, R. G. (1998). Changing attentional bias: Can it effect self- reported anxiety? *Anxiety, Stress and Coping*, *11*(2), 167–179. https://doi.org/10.1080/10615809808248310

Hedge, C., Powell, G., & Sumner, P. (2018). The reliability paradox: Why robust cognitive tasks do not produce reliable individual differences. *Behavior Research Methods*, *50*(3), 1166–1186. https://doi.org/10.3758/s13428-017-0935-1

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*(7), 622–629. https://doi.org/10.1136/adc.2010.191312

Henderson, H. A., Pine, D. S., & Fox, N. A. (2015). Behavioral inhibition and developmental risk: A dual-Processing perspective. *Neuropsycho-pharmacology*, 207–224. https://doi.org/10.1038/npp.2014.189

Hessels, R. S., Kemner, C., & Boomen, C. Van Den. (2016). The area-of-interest problem in eyetracking research: A noise-robust solution for face and sparse stimuli. *Behavior Research Methods*, 1694–1712. https://doi.org/10.3758/s13428-015-0676-y

Hessels, R. S., Niehorster, D. C., Kemner, C., & Hooge, I. T. C. (2017). Noise-robust fixation detection in eye movement data: Identification by two-means clustering (I2MC). *Behavior Research Methods*, *49*, 1802–1823. https://doi.org/10.3758/s13428-016-0822-1

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

Hood, B. M., Douglas Willen, J., & Driver, J. (1998). Adult's eyes trigger shifts of visual attention in human infants. *Psychological Science*, *9*(2), 131–134. https://doi.org/10.1111/1467-9280.00024

Huber, L., Plötner, M., & Schmitz, J. (2019). Social competence and psychopathology in early childhood: a systematic review. *European Child and Adolescent Psychiatry*, *28*(4), 443–459. https://doi.org/10.1007/s00787-018-1152-x

Huizink, A. C., Delforterie, M. J., Scheinin, N. M., Tolvanen, M., Karlsson, L., & Karlsson, H. (2016). Adaption of pregnancy anxiety questionnaire–revised for all pregnant women regardless of parity: PRAQ-R2. *Archives of Women's Mental Health*, *19*(1), 125–132. https://doi.org/10.1007/s00737-015-0531-2

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*(4), 335–344.

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

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

Kammermeier, M., Duran Perez, L., König, L., & Paulus, M. (2020). Attachment security and attention to facial emotional expressions in preschoolers: An eye-tracking study. *British Journal of Developmental Psychology*, *38*(2), 167–185. https://doi.org/10.1111/bjdp.12313

Kammermeier, M., & Paulus, M. (2022). Maternal sensitivity and non-intrusiveness at 12 months predict attention to emotional facial expressions at 24 months: A cross-lagged panel. *Social Development*, *31*(November 2020), 319–338. https://doi.org/10.1111/sode.12561

Kappenman, E. S., Farrens, J. L., Luck, S. J., & Proudfit, G. H. (2014). Behavioral and ERP measures of attentional bias to threat in the dot-probe task: Poor reliability and lack of correlation with anxiety. *Frontiers in Psychology*, *5*(DEC), 1–9. https://doi.org/10.3389/fpsyg.2014.01368

Karlsson, L., Tolvanen, M., Scheinin, N. M., Uusitupa, H., Korja, R., Ekholm, E., Tuulari, J. J., Pajulo, M., Huotilainen, M., Paunio, T., & Karlsson, H. (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., Eskola, E., Pelto, J., Korja, R., Paija, S.-P., Nolvi, S., … Leppänen, J. M. (2022). The stability of early developing attentional bias for faces and fear from 8 to 30 and 60 months in the FinnBrain Birth Cohort Study. *Developmental Psychology*. https://doi.org/10.1037/dev0001432.supp

Kataja, E.-L., Karlsson, L., Leppänen, J. M., Pelto, J., Häikiö, T., Nolvi, S., … Karlsson, H. (2020). Maternal depressive symptoms during the pre- and postnatal periods and infant attention to emotional faces. *Child Development*, *91*, e475–e490. 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). 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

Kaukiainen, A., Salmivalli, C., Lagerspetz, K., Tamminen, M., Vauras, M., Mäki, H., & Poskiparta, E. (2002). Learning difficulties, social intelligence, and self-concept: Connections to bully-victim problems. *Scandinavian Journal of Psychology*, *43*(3), 269–278. https://doi.org/10.1111/1467-9450.00295

Kenward, B., Koch, F. S., Forssman, L., Brehm, J., Tidemann, I., Sundqvist, A., … Gredebäck, G. (2017). Saccadic reaction times in infants and adults: Spatiotemporal factors, gender, and interlaboratory variation. *Developmental Psychology*, *53*(9), 1750–1764. https://doi.org/10.1037/dev0000338

Kleberg, J. L., del Bianco, T., & Falck-Ytter, T. (2018). How infants arousal influences their visual search. *Child Development*, *31 Dec*. https://doi.org/10.1111/cdev.13198

Klin, A., Shultz, S., & Jones, W. (2015). Social visual engagement in infants and toddlers with autism: Early developmental transitions and a model of pathogenesis. *Neuroscience and Biobehavioral Reviews*, *50*, 189–203. https://doi.org/10.1016/j.neubiorev.2014.10.006

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*(2), 339–345. https://doi.org/10.1542/peds.2013-1204

Kotsoni, E., De Haan, M., & Johnson, M. H. (2001). Categorical perception of facial expressions by 7-month-old infants. *Perception*, *30*(9), 1115–1125. https://doi.org/10.1068/p3155

Kruijt, A.-W., Parsons, S., & Fox, E. (2019). A meta-analysis of bias at baseline in RCTs of attention bias modification: No evidence for dot-probe bias towards threat in clinical anxiety and PTSD. *Journal of Abnormal Psychology*, *128*(6), 563–573. https://doi.org/10.1037/abn0000406

Lagattuta, K. H., & Kramer, H. J. (2017). Try to look on the bright side: Children and adults can (sometimes) override their tendency to prioritize negative faces. *Journal of Experimental Psychology: General*, *146*(1), 89–101. https://doi.org/10.1037/xge0000247

Lee, V., Cheal, J. L., & Rutherford, M. D. (2015). Categorical perception along the happy–angry and happy–sad continua in the first year of life. *Infant Behavior and Development*, *40*, 95–102. https://doi.org/10.1016/j.infbeh.2015.04.006

Lee, V., Da Silva, N., & Rutherford, M. D. (2020). Toddlers categorically perceive emotional facial expressions along a happy–sad continuum. *Perception*, *49*(8), 822–834. https://doi.org/10.1177/0301006620944844

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*(5), 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*(2), 538–548. https://doi.org/10.3758/s13428-014-0473-z

Leppänen, J. M., & Nelson, C. A. (2012). Early development of fear processing. *Current Directions in Psychological Science*, *21*(3), 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*(11), 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*(3), 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*(NOV), 1–10. https://doi.org/10.3389/fpsyg.2017.01976

Lindblom, J., Peltola, M. J., Va, M., Hietanen, J. K., Laakso, A., & Tiitinen, A. (2017). Early family system types predict children's emotional attention biases at school age. *International Journal of Behavioral Development*, *4*(2), 245–256. https://doi.org/10.1177/0165025415620856

Lobue, V. (2014). Measuring attentional biases for threat in children and adults. *Journal of Visualized Experiments*, *92*(October). https://doi.org/10.3791/52190

Lobue, V., & DeLoache, J. S. (2010). Superior detection of threat-relevant stimuli in infancy. *Developmental Science*, *13*(1), 221–228. https://doi.org/10.1111/j.1467-7687.2009.00872.x

Loman, M. M., & Gunnar, M. R. (2010). Early experience and the development of stress reactivity and regulation in children. *Neuroscience and Biobehavioral Reviews*, *34*(6), 867–876. https://doi.org/10.1016/j.neubiorev.2009.05.007

Long, J., Powell, C., Bamber, D., Garratt, R., Brown, J., & Dyson, S. (2018). Development of materials to support parents whose babies cry excessively: findings and health service implications. *Primary Health Care Research & Development*, *19*, 320–332. https://doi.org/10.1017/S1463423617000779

Lovejoy, M. C., Graczyk, P. A., O'Hare, E., & Neuman, G. (2000). Maternal depression and parenting behavior. *Clinical Psychology Review*, *20*(5), 561–592. https://doi.org/10.1016/s0272-7358(98)00100-7

Machulska, A., Kleinke, K., & Klucken, T. (2022). Same same, but different: A psychometric examination of three frequently used experimental tasks for cognitive bias assessment in a sample of healthy young adults. *Behavior Research Methods*, (0123456789). https://doi.org/10.3758/s13428-022-01804-9

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology*, *95*(1), 15–20. https://doi.org/10.1037/0021-843X.95.1.15

MacLeod, C., Rutherford, E., Campbell, L., Ebsworthy, G., & Holker, L. (2002). Selective attention and emotional vulnerability: Assessing the causal basis of their association through the experimental manipulation of attentional bias. *Journal of Abnormal Psychology*, *111*(1), 107–123. https://doi.org/10.1037/0021-843X.111.1.107

Madigan, S., Prime, H., Graham, S. A., Rodrigues, M., Anderson, N., Khoury, J., & Jenkins, J. M. (2019). Parenting behavior and child language: A Meta-analysis. *Pediatrics*, *144*(4). https://doi.org/10.1542/peds.2018-3556

Marsh, A. A. (2016a). Neural, cognitive, and evolutionary foundations of human altruism. *WIREs Cognitive Science*, *7*(February), 59–71. https://doi.org/10.1002/wcs.1377

Marsh, A. A. (2016b). Understanding amygdala responsiveness to fearful expressions through the lens of psychopathy and altruism. *Journal of Neuroscience Research*, *94*(6), 513–525. https://doi.org/10.1002/jnr.23668

Marsh, A. A. (2019). The caring continuum: Evolved hormonal and proximal mechanisms explain prosocial and antisocial extremes. *Annual Review of Psychology*, *70*(1), 347–371. https://doi.org/10.1146/annurev-psych-010418-103010

Masten, A. S., Coatsworth, J. D., Neemann, J., Gest, S. D., Tellegen, A., & Garmezy, N. (1995). The structure and coherence of competence from childhood through adolescence. *Child Development*, *66*(6), 1635–1659. https://doi.org/10.1111/j.1467-8624.1995.tb00956.x

McLeod, B. D., Weisz, J. R., & Wood, J. J. (2007). Examining the association between parenting and childhood depression: A meta-analysis. *Clinical Psychology Review*, *27*(8), 986–1003. https://doi.org/10.1016/j.cpr.2007.03.001

Mesman, J., & Koot, H. M. (2001). Early preschool predictors of preadolescent internalizing and externalizing DSM-IV diagnoses. *Journal of the American Academy of Child & Adolescent Psychiatry*, *40*(9), 1029–1036. https://doi.org/10.1097/00004583-200109000-00011

Mogg, K., & Bradley, B. P. (2018). Anxiety and threat-related attention: Cognitive-motivational framework and treatment. *Trends in Cognitive Sciences*, *22*(3), 225–240. https://doi.org/10.1016/j.tics.2018.01.001

Möller, E. L., Nikolić, M., Majdandžić, M., & Bögels, S. M. (2016). Associations between maternal and paternal parenting behaviors, anxiety and its precursors in early childhood: A meta-analysis. *Clinical Psychology Review*, *45*, 17–33. https://doi.org/10.1016/j.cpr.2016.03.002

Monk, C. S., Nelson, E. E., McClure, E. B., Mogg, K., Bradley, B. P., Leibenluft, E., … Pine, D. S. (2006). Ventrolateral prefrontal cortex activation and attentional bias in response to angry faces in adolescents with generalized anxiety disorder. *American Journal of Psychiatry*, *163*(6), 1091–1097. https://doi.org/10.1176/ajp.2006.163.6.1091

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*(5), 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. *Develomental Cognitive Neuroscience*, *21*, 26–41. https://doi.org/10.1016/j.dcn.2016.08.001

Morales, S., Pérez-Edgar, K., & Buss, K. (2016). Longitudinal relations among exuberance, externalizing behaviors, and attentional bias to reward: the mediating role of effortful control. *Developmental Science*, *19*, 853–862. https://doi.org/10.1111/desc.12320

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

Morales, S., Taber-Thomas, B. C., & Pérez-Edgar, K. (2017). Patterns of attention to threat across tasks in behaviorally inhibited children at risk for anxiety. *Developmental Science*, *20*. https://doi.org/10.1111/desc.12391

Nakagawa, A., & Sukigara, M. (2012). Difficulty in disengaging from threat and temperamental negative affectivity in early life: A longitudinal study of infants aged 12 to 36 months. *Behavioral and Brain Functions*, *8*(1), 40. https://doi.org/10.1186/1744-9081-8-40

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*(May 2019), 38–45. https://doi.org/10.1016/j.infbeh.2019.02.004

Nava, E., Romano, D., Grassi, M., & Turati, C. (2016). Skin conductance reveals the early development of the unconscious processing of emotions. *Cortex*, *84*, 124–131. https://doi.org/10.1016/j.cortex.2016.07.011

Nelson, C. A., & Dolgin, K. G. (1985). The generalized discrimination of facial expressions by seven-month-old infants. *Child Development*, *56*(1), 58–61.

Öhman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review*, *108*(3), 483–522. https://doi.org/10.1037/0033-295X.108.3.483

Olsen, A. L., Ammitzbøll, J., Olsen, E. M., & Skovgaard, A. M. (2019). Problems of feeding , sleeping and excessive crying in infancy : a general population study. *Archives of Disease in Childhood*, *104*, 1034–1041. https://doi.org/10.1136/archdischild-2019-316851

Otte, R. A., Donkers, F. C. L., Braeken, M. A. K. A., & Van den Bergh, B. R. H. (2015). Multimodal processing of emotional information in 9-month-old infants II: Prenatal exposure to maternal anxiety. *Brain and Cognition*, *95*, 107–117. https://doi.org/10.1016/j.bandc.2014.12.001

Pauli-Pott, U., Becker, K., Mertesacker, T., & Beckmann, D. (2000). Infants with "Colic" - Mothers' perspectives on the crying problem. *Journal of Psychosomatic Research*, *48*(2), 125–132. https://doi.org/10.1016/S0022-3999(99)00084-7

Peltola, M. J., Forssman, L., Puura, K., Van IJzendoorn, M. H., & Leppänen, J. M. (2015). Attention to faces expressing negative emotion at 7 months predicts attachment security at 14 months. *Child Development*, (5), 1321–1332. https://doi.org/10.1111/cdev.12380

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., van IJzendoorn, M. H., & Yrttiaho, S. (2020). Attachment security and cortical responses to fearful faces in infants. *Attachment & Human Development*, *22*(2), 174–188. https://doi.org/10.1080/14616734.2018.1530684

Peltola, M. J., Yrttiaho, S., & Leppänen, J. M. (2018). Infants' attention bias to faces as an early marker of social development. *Developmental Science*, (March 2017), 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*(3), 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*(12), 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*(6), 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*(11), 773–782. https://doi.org/10.1038/nrn2920

Pfaff, D. W., Kavaliers, M., & Choleris, E. (2008). Mechanisms underlying an ability to behave ethically. *The American Journal of Bioethics*, *8*(5), 9–19. https://doi.org/10.1080/15265160802179994

Pollak, S. D. (2015). Multilevel developmental approaches to understanding the effects of child maltreatment: Recent advances and future challenges. *Development and Psychopathology*, *27*, 1387–1397. https://doi.org/10.1017/S0954579415000826

Pollak, S. D., & Kistler, D. J. (2002). Early experience is associated with the development of categorical representations for facial expressions of emotion. *PNAS*, *99*(13), 9072–9076.

Pollak, S. D., & Sinha, P. (2002). Effects of early experience on children's recognition of facial displays of emotion. *Developmental Psychology*, *38*(5), 784–791. https://doi.org/10.1037/0012-1649.38.5.784

Posner, M. I., Walker, J. A., Friedrich, F. J., & Rafal, R. D. (1984). Effects of parietal injury on covert orienting of attention. *The Journal of Neuroscience*, *4*(7), 1863–1874.

Posner, Michael 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

Putnam, S. P., Helbig, A. L., Gartstein, M. A., Rothbart, M. K., & Leerkes, E. (2014). Development and assessment of short and very short forms of the infant behavior questionnaire-revised. *Journal of Personality Assessment*, *96*(4), 445–458. https://doi.org/10.1080/00223891.2013.841171

Pyykkö, J., Ashorn, P., Ashorn, U., Niehaus, D. J. H., & Leppänen, J. M. (2019). Cross-cultural analysis of attention disengagement times supports the dissociation of faces and patterns in the infant brain. *Scientific Reports*, *9*(1), 1–10. https://doi.org/10.1038/s41598-019-51034-x

Pyykkö, J., Forssman, L., Maleta, K., Ashorn, P., Ashorn, U., & Leppänen, J. M. (2018). Early development of visual attention in infants in rural Malawi. *Developmental Science*, (May), 1–17. https://doi.org/10.1111/desc.12761

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

R Core Team (2020). R: *A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. Available at https://www.R-project.org/.

R Core Team (2021). R: *A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. Available at https://www.R-project.org/.

Rajhans, P., Altvater-Mackensen, N., Vaish, A., & Grossmann, T. (2016). Children's altruistic behavior in context: The role of emotional responsiveness and culture. *Scientific Reports*, *6*, 1–6. https://doi.org/10.1038/srep24089

Ramsey, J. L., Langlois, J. H. (2002). How infants perceive faces. In A. Slater & M. Lewis (Eds.) *Introduction to Infant Development.* Oxford: Oxford University Press.

Reid, V. M., Dunn, K., Young, R. J., Amu, J., Donovan, T., & Reissland, N. (2017). The human fetus preferentially engages with face-like visual stimuli. *Current Biology*, *27*(12), 1825-1828.e3. https://doi.org/10.1016/j.cub.2017.05.044

Reynolds, G. D., & Roth, K. C. (2018). The development of attentional biases for faces in infancy: A developmental systems perspective. *Frontiers in Psychology*, *9*(February), 1–16. https://doi.org/10.3389/fpsyg.2018.00222

Rodenbauch, T. L., Scullin, R. B., Langer, J. K., Dixon, D. J., Huppert, J. D., Bernstein, A., … Lenze, E. J. (2016). Unreliability as a threat to understanding psychopathology: The cautionary tale of attentional bias. *Journal of Abnormal Psychology*, *125*(6), 840–851. https://doi.org/10.1037/abn0000184.

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.* New Jersey: Earlbaum.

Rothbart, M. K., Sheese, B. E., Rueda, M. R., & Posner, M. I. (2011). Developing mechanisms of self-regulation in early life. *Emotion Review*, *3*(2), 207–213. https://doi.org/10.1177/1754073910387943

Roy, A. M. Y. K., Vasa, R. A., Bruck, M., Mogg, K., Bradley, B. P., Sweeney, M., & Bergman, R. L. (2008). Attention bias toward threat in pediatric anxiety disorders. *Journal of the American Academy of Child & Adolescent Psychiatry*, *47*(10), 1189–1196. https://doi.org/10.1097/CHI.0b013e3181825ace

Rubin, K. H., Bukowski, W. M., & Parker, J. G. (2006). Peer interactions, relationships, and groups. In N. Eisenberg, W. Damon, & R. M. Lerner (Eds.), *Handbook of child psychology: Social, emotional, and personality development* (pp. 571–645). John Wiley & Sons, Inc.

Samdan, G., Kiel, N., Petermann, F., Rothenfußer, S., Zierul, C., & Reinelt, T. (2020). The relationship between parental behavior and infant regulation: A systematic review. *Developmental Review*, *57*, 100923. https://doi.org/10.1016/j.dr.2020.100923

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. (2011). Predictors of crying, feeding and sleeping problems: a prospective study. *Child: Care, Health and Development*, *37*(4), 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*(8), 399–405. https://doi.org/10.1016/j.earlhumdev.2014.05.001

Schmukle, S. C. (2005). Unreliability of the dot probe task. *European Journal of Personality*, *19*(7), 595–605. https://doi.org/10.1002/per.554

Schwartz, G. M., Izard, C. E., & Ansul, S. E. (1985). The 5-month-old's ability to discriminate facial expressions of emotion. *Infant Behavior and Development*, *8*, 65–77. https://doi.org/10.1016/S0163-6383(85)80017-5

Senju, A., & Johnson, M. H. (2009). The eye contact effect: mechanisms and development. *Trends in Cognitive Sciences*, *13*(3), 127–134. https://doi.org/10.1016/j.tics.2008.11.009

Seymour, M., Giallo, R., Cooklin, A., & Dunning, M. (2015). Maternal anxiety, risk factors and parenting in the first post-natal year. *Child: Care, Health and Development*, *41*(2), 314–323. https://doi.org/10.1111/cch.12178

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*(4), 282–294. https://doi.org/10.1002/da.20914

Shechner, T., Ph, D., Jarcho, J. M., Britton, J. C., Leibenluft, E., Pine, D. S., & Nelson, E. E. (2013). Attention bias of anxious youth during eye-tracking study. *Depression and Anxiety*, *21*, 14–21. https://doi.org/10.1002/da.21986

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*(3), 293–302. https://doi.org/10.1007/s00787-016-0888-4

Stekhoven, D. J., & Bühlmann, P. (2012). Missforest-Non-parametric missing value imputation for mixed-type data. *Bioinformatics*, *28*(1), 112–118. https://doi.org/10.1093/bioinformatics/btr597

Symons, L. A., Hains, S. M. J., & Muir, D. W. (1998). Look at me: Five-month-old infants' sensitivity to very small deviations in eye-gaze during social interactions. *Infant Behavior and Development*, *21*(3), 531–536. https://doi.org/10.1016/S0163-6383(98)90026-1

Taylor-Colls, S., & Fearon, R. M. P. (2015). The effects of parental behavior on infants' neural processing of emotion expressions. *Child Development*, *86*(3), 877–888. https://doi.org/10.1111/cdev.12348

Teicher, M. H., & Samson, J. A. (2016). Annual Research Review: Enduring neurobiological effects of childhood abuse and neglect. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *57*(3), 241–266. https://doi.org/10.1111/jcpp.12507

Thiel-Bonney, C., & Cierpka, M. (2016). Excessive crying. In Cierpka (Eds.), *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*(7), 365–372. https://doi.org/dx.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*(6), 847–859. https://doi.org/10.1007/s00787-018-1243-8

Tottenham, N., Hare, T. A., Quinn, B. T., McCarry, T. W., Nurse, M., Gilhooly, T., … Casey, B. J. (2010). Prolonged institutional rearing is associated with atypically large amygdala volume and difficulties in emotion regulation. *Developmental Science*, *13*(1), 46–61. https://doi.org/10.1111/j.1467-7687.2009.00852.x

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., … Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research, 168(3),* 242–249. https://doi.org/10.1038/jid.2014.371

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

Vallorani, A., Fu, X., Morales, S., LoBue, V., Buss, K. A., & Pérez-Edgar, K. (2021). Variable- and person-centered approaches to affect-biased attention in infancy reveal unique relations with infant negative affect and maternal anxiety. *Scientific Reports*, *11*(1), 1–14. https://doi.org/10.1038/s41598-021-81119-5

Vallorani, A., Gunther, K. E., Anaya, B., Burris, J. L., Field, A. P., Lobue, V., … Pérez-edgar, K. (2023). Assessing bidirectional relations between infant temperamental negative affect, maternal anxiety symptoms and infant affect-biased attention across the first 24-months of life. *Developmental Psychology*, *59*(2), 364–376. doi: 10.1037/dev0001479.

Van Bockstaele, B., Verschuere, B., Tibboel, H., De Houwer, J., Crombez, G., & Koster, E. H. W. (2014). A review of current evidence for the causal impact of attentional bias on fear and anxiety. *Psychological Bulletin*, *140*(3), 682–721. https://doi.org/10.1037/a0034834

Van IJzendoorn, M. H., & Bakermans-Kranenburg, M. J. (2014). Genetic differential susceptibility on trial: Meta-analytic support from randomized controlled experiments. *Development and Psychopathology*, *27*(1), 151–162. https://doi.org/10.1017/S0954579414001369

Walle, E. A., Reschke, P. J., Camras, L. A., & Campos, J. J. (2017). Infant differential behavioral responding to discrete emotions. *Emotion*, *17*(7), 1078–1091. https://doi.org/10.1037/emo0000307.Infant

Wass, S. V. (2018). How orchids concentrate? The relationship between physiological stress reactivity and cognitive performance during infancy and early childhood. *Neuroscience and Biobehavioral Reviews*, *90*(March), 34–49. https://doi.org/10.1016/j.neubiorev.2018.03.029

Wickham, H., 2009. *ggplot2: Elegant Graphics For Data Analysis.* New York, NY: Springer-Verlag.

York.Wolke, D. (2019). Persistence of infant crying , sleeping and feeding problems : need for prevention. *Archives of Disease in Childhood*, *104*(11). https://doi.org/10.1111/cdev.13155.

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

Yiend, J. (2010). The effects of emotion on attention: A review of attentional processing of emotional information. *Cognition and Emotion*, *24*(1), 3–47. https://doi.org/10.1080/02699930903205698

Young-Browne, G., Rosenfeld, H. M., & Horowitz, F. D. (1977). Infant discrimination of facial expressions. *Child Development*, *48*, 555–562. https://doi.org/10.2307/1128653

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*(6), e100811. https://doi.org/10.1371/journal.pone.0100

TURUN YLIOPISTO
UNIVERSITY OF TURKU

Painosalama, Turku, Finland 2024

ISBN 978-951-29-9678-0 (PRINT)
ISBN 978-951-29-9679-7 (PDF)
ISSN 0082-6987 (Print)
ISSN 2343-3191 (Online)