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Reciprocal Relationships Between a Child's Engagement with Faces and Mother-Child Interaction at 8, 30, and 60 Months

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Abstract

Prioritized attention to faces can be viewed as an early-developing marker of social engagement. This behavior is closely linked with early interactions, but there has been little research examining the longitudinal associations between social engagement and parent-child interaction. We examined the reciprocal relations between mother-child interaction and child engagement with faces from infancy to preschool age. Participants of this study were 738 mother-child dyads from the FinnBrain Birth Cohort. We used Emotional Availability (EA) Scales to examine mothers' emotional availability in interaction and eye tracking to examine attention dwell time for pictured faces and non-face patterns under distraction at 8, 30, and 60 months. Using a random intercept cross-lagged panel model, which differentiates between-dyad variance from within-dyad variance (deviations from the individual's latent average), we found that higher maternal emotional availability was associated with shorter dwell time for faces at the between-dyad level. At the within-dyad level, stability (smaller deviations from the individual's latent average) in a mother's emotional availability at 30 months was associated with stability in the child's face engagement in the subsequent assessment at 60 months. Similar associations were not found in analyses of dwell times for non-faces. Together, our findings show an interconnection between mother-child interaction and the child's engagement with faces and raise the possibility that shifts in the quality of these interactions within specific developmental stage may lead to changes in how children engage with social cues.

Impact Statement

This study examined how children's engagement with faces is related to the interaction between the child and the mother across early to mid-childhood. Understanding the origins of individual differences in attention to faces during early childhood is important, as this behavior is a correlate of social-emotional development. Our analysis of longitudinal data implicated that overall, higher emotional availability in mother-child interaction was related to shorter dwell times on pictures of faces on a computer screen across the first five years. Aside from this time-invariant association between the two constructs, we also found indications that a change in maternal emotional availability within a specific developmental stage in toddlerhood may be followed by a change in the child's face engagement.

Introduction

Prioritized attention to faces, present immediately after birth (Johnson et al., 2015), is a key aspect of human visual behavior and can be viewed as an early marker of social engagement. Faces hold information about others' inner states, which makes them important for the ability to process and respond appropriately to others' intentions and experiences, an essential part of child social, cognitive, and emotional development (Grossmann & Johnson, 2007; Klin et al., 2015; Reynolds & Roth, 2018). In previous studies, visual engagement with faces and facial expressions of emotion in infancy have been linked to prosocial behaviors in early childhood (Bedford et al., 2015; Donohue et al., 2024; Eskola et al., 2023; Grossmann et al., 2018; Peltola et al., 2018) and trajectories of social-emotional development (Morales et al., 2016), while lower levels of face engagement (i.e. decreased attention to faces) have been linked with atypical social-emotional development, such as callous-unemotional behaviors (Bedford et al., 2015; Peltola et al., 2018) and autism (Jones & Klin, 2013). Tendency to orient towards faces is thought to support reciprocal interactions and bonding with the caregiver, therefore having a relevant connection to parent-child interaction (Beebe et al., 2016; Leong et al., 2017; Markova & Siposova, 2019). Presumably, interactions with primary caregivers hold a key role in the development of face engagement although there has been very little research examining whether and how the development of engagement with faces in children is associated and potentially shaped by the quality of early interactions between the child and the parent.

Newborn infants exhibit preferential turning of the head and gaze toward face-like patterns (Johnson, 2005; Reynolds & Roth, 2018), and by 3 months of age, infants can already detect faces in less than a second in complex naturalistic visual scenes (Kelly et al., 2019). During the second half of the first year, infants start to look longer at faces than other salient stimuli, suggesting that attention to faces becomes more resistant to distraction (Leppänen, 2016). In addition to this general bias towards faces, prioritized processing of fearful faces emerges between five and seven months of age (Heck et al., 2016; Nelson & Dolgin, 1985; Peltola et al., 2013), possibly because of the specific visual features, novelty, or affective signal value of this expression (Johnson, 2005; Leppänen et al., 2018).

While infants dwell longer on faces than objects, the strength of this bias varies between individuals (Pyykkö et al., 2019). These variations are correlated with, but not fully explained, by dwell time for non-face patterns (Pyykkö et al., 2019). Further, dwell times for different facial expressions are strongly correlated in infants (Peltola et al., 2018; Pyykkö et al., 2019). Together, these results suggest that the variations may reflect individual differences in a broader tendency for face engagement rather than potential emotion-specific biases. Preliminary evidence further suggests that the face bias diminishes after the first year of life, and individual variations in this bias are not stable from infancy to later childhood, at least not between 7 and 24 months (Peltola et al., 2018), from 5 or 12 months to 36 months (Xie et al., 2021). However, a recent study (E.-L. Kataja et al., 2022) with a longer follow-up reported that the decline in face bias between infancy and toddlerhood might be followed by a partial return of the bias between 30 and 60 months and that there is a weak stability in face bias from 8 to 60 months. Different developmental patterns have been found for emotion-specific biases, including a general decline in the fear bias from infancy to mid childhood (E.-L. Kataja et al., 2022) or developmental changes towards faster detection of angry faces and longer time spent engaging with angry over neutral faces over the first two years of life (Reider et al., 2022). Together, these results suggest that the general tendency to attend towards faces and the biases for specific emotions are based on different attention mechanisms, possibly serving different functions developmentally.

Individual differences in face engagement have been ascribed to genetic origins (Constantino et al., 2017), but there are also indications that engagement with faces may be affected by environmental factors (Reynolds & Roth, 2018), including parent-child interaction. Further, developmental theories and data suggest that social information processing (Dykas & Cassidy, 2011) and development of constructs that are closely related to attention, such as self-regulation (Samdan et al., 2020), are affected by early experiences in social interactions with the caregiver. However, longitudinal data on the relation between face engagement and early parent-child interaction are scarce. Hence, our goal in this study was to further investigate to what extent variations in engagement with faces are associated with mother-child interaction, a key environmental factor for child development, in early to mid-childhood. We used Emotional Availability (EA), a well-established construct of parent-child interaction emphasizing dyadic and emotional qualities of adult–child relationships (Biringen, 2008), to assess the quality of the interaction. Based on the attachment theory (Bowlby, 1969), the construct of emotional availability comprises 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 EA assessment (Biringen, 2008) consists of four dimensions measuring the adult’s emotions and behaviors, including both positive (sensitivity, structuring) and negative indicators (intrusiveness, hostility). Maternal emotional availability has been shown to be related to child’s emotion regulation, emotional understanding, and school readiness (Saunders et al., 2015).

Questions similar to this study have been addressed in recent studies that have used eye tracking to examine how infant’s attention towards specific facial expressions are associated with maternal emotional availability or other features of early environment. A cross-sectional study, using partly overlapping sample and similar methodology as the current study, found reduced disengagement from fearful faces to be associated with lower maternal overall emotional availability in 8-month-old infants (Eskola et al., 2024). In another longitudinal study, maternal sensitivity and non-intrusiveness at 12 months were found to predict increased attention to emotional facial expressions during free-viewing of faces displayed one by one at 24 months (Kammermeier & Paulus, 2021). Finally, increased face-sensitive event-related brain responses to positive facial expressions in infancy have been associated with higher maternal overall emotional availability (Taylor-Colls & Pasco Fearon, 2015). In addition to these findings from studies that have specifically focused on linking attention to specific facial expressions with parent-child interaction, there are also findings suggesting that biases towards specific facial expressions in infants are associated with maternal anxiety (E. L. Kataja et al., 2019; Morales et al., 2017; Vallorani et al., 2021, 2023), maternal stress and depressive symptoms (Forssman et al., 2014; E. L. Kataja et al., 2020), parental negative affect (Aktar et al., 2018), child attachment style (Forslund et al., 2019; Kammermeier et al., 2020; Peltola et al., 2015, 2020), as well as maltreatment and hostility of family environment (Gulley et al., 2014; Lindblom et al., 2015; Mastorakos & Scott, 2019; Pollak, 2015).

Although previous research suggests a link between child's engagement with facial cues and different aspects of early environment, most of this research has focused on children's attentional biases for specific emotions instead of attention to faces more generally. The results showing high correlations of attentional dwell time for faces displaying different emotions and lower correlations of dwell times for faces and non-face pattern suggests existence of a common "face factor" that may explain much of the individual variations in attention dwell times for different facial cues (Pyykkö et al., 2019). Because variations in face engagement may be a correlate of broader social development in early childhood, it would be important to use longitudinal study designs and data modelling (Vallorani et al., 2023) to examine whether and how individual differences are associated with the characteristics of mother-child interaction.

The aim of this exploratory study was to examine the reciprocal relations between maternal emotional availability in mother-child interaction and child engagement with faces from infancy to preschool age. We used the maternal variables of the EA Scales (Biringen, 2008) to assess mother-child interaction, and eye tracking to examine attention dwell time for faces under distraction (i.e., presentation of a salient lateral stimulus) at 8, 30, and 60 months. We formed one maternal EA factor including maternal sensitivity, structuring, non-intrusiveness, and non-hostility variables and one face engagement factor based on observed dwell times for each face condition (happy/ neutral/ fearful) for each measurement timepoint. By modeling longitudinal data with a random intercept cross-lagged panel model (RI-CLPM), we investigated the relationship between maternal emotional availability and a child's engagement with faces between and within dyads. Compared to more conventional approaches, this method takes into account the trait-like, time-invariant differences in a mother's behavior as well as in a child's behavior and their relationship, while also allowing for the assessment of within-dyad dynamics over time (Hamaker et al., 2015). Within the RI-CLPM framework, we can evaluate whether deviations from an individual's typical level of a behavior or characteristic (latent average) are related across different constructs. These deviations can demonstrate either stability or fluctuation. Stability refers to smaller deviations from the latent average, indicating consistent behavior over time, while fluctuation refers to larger deviations, indicating significant changes over time (see also Vallorani et al., 2023).

Based on the theoretical account and previous studies linking child's face engagement with emotional qualities of mother-child interaction or maternal characteristics more broadly, we expected to find associations between maternal emotional availability and child engagement with faces at the between-dyads and within-dyad level investigation. However, prior results are conflicting regarding the direction of the association, as positive aspects of mother-child interaction have been found to be associated with increased and decreased engagement with facial expressions of emotion (Eskola et al., 2024; Kammermeier & Paulus, 2021). To our knowledge, previous studies have not applied the same methodological approach to a similar longitudinal sample as used in the current study. Thus, prior research does not support a strong hypothesis concerning the direction of the linkage between face engagement and maternal emotional availability between-dyads nor the within-dyad dynamics. Therefore, these is a need for further exploratory analyses of this association with longitudinal data, which we report in this study.

Methods

Participants

This study is part of multidisciplinary longitudinal FinnBrain Birth Cohort Study (Karlsson et al., 2018) aiming to study the environmental and genetic factors associated with child development, and planned to continue for several decades. The main cohort (N = 3808), representative of the northern European source population (Karlsson et al., 2018), was gathered from the South-Western Hospital District and the Åland Islands in Finland between 2011 and 2015. Mothers and their spouses were recruited during their first trimester ultrasound at gestational week 12. A subset of the main cohort is a Focus Cohort (N = 1227), which comprises of mother-infant dyads with high or low prenatal stress. The aim for the Focus Cohort was to be able to assess the effects of high versus low prenatal stress on child development. Prenatal stress was assessed at gestational week 14, 24, and 34 with the Edinburgh Postnatal Depression Scale (EPDS; (Cox et al., 1987), Symptom Checklist-90, Anxiety scale (SCL-90; (Holi et al., 1998), and Pregnancy Related Anxieties Questionnaire-Revised (Huizink et al., 2016). The criteria for the Focus Cohort are outlined in the report by Karlsson et al. (2018). Participants of this study are included in the Focus Cohort diversified by mother-child dyads from the basic cohort population to ensure a representative distribution of maternal prenatal distress across the study population. Characteristics of the final sample of the current study are shown in Table 1.

Mother-infant dyads included in this study were invited to participate in study visits at the Child Development and Parental Functioning Lab, consisting of child eye tracking, cognitive development, executive function, and temperament measures together with mother-child-interaction procedure at the child's age of 8, 30, and 60 months. Participants of this study participated in the eye tracking procedure and mother-child interaction procedure at one or more timepoints. There were some participants who participated only in the eye tracking procedure. At the time of the current study, complete data from mother-child interaction procedure at 60 months was not available as the analysis was still ongoing. Total number of participants for mother-child procedure were 181 at 8-month assessment, 355 at 30-month assessment, and 263 at 60-month assessment, and for eye tracking 363 at 8-month assessment, 333 at 30-month assessment, and 437 at 60-month assessment. All participants with data available and passing the exclusion criteria (as explained below) from one or more timepoints were used in the current analyses, resulting in a total number of participants N = 738.

During the laboratory visits, the mothers gave written informed consent on behalf of their children. They were informed about the study details and their option to withdraw from the testing at any time without providing a specific reason. The Ethics Committee of the Hospital District of Southwest Finland approved the study protocol. The study was conducted in full compliance with the Helsinki Declaration.

Table 1
Demographic Characteristics for Final Sample (N = 738)

Characteristic	Statistics (*N* =738)
Boys, N (%)	406 (55)
Girls, N (%)	332 (45)
GA (weeks), M (range)	39.8 (30.1–42.4)
Mother age at delivery, M (SD)	30.99 (4.51)
Maternal education, N (%)	
High school/vocational	192 (26)
Polytechnics	214 (29)
University	311 (42)
Data missing	21 (3)
Maternal prenatal distress, N (%)	
High	191 (26)
Low	306 (41)
Other	241 (33)

Note. GA = Gestational age.

Mother-Child Interaction Procedure at 8, 30, and 60 Months

The mother–child interaction was assessed from a video-recorded play situation in a quiet laboratory setting. For the free-play part, parent and child were offered a standard set of age-appropriate toys and the mother was instructed to play with her child with or without the toys, as they would play at home. Afterwards, mother-child interaction was coded using the Emotional Availability (EA) Scales (Biringen, 2008). Using the EA Scales requires training and certification. The procedure had some differences between timepoints; 8-month assessment included a 20-min free play situation analyzed as a whole, 30-month assessment consisted of a 5-min structured task in addition to a 15-min free-play which were analyzed together, while 60-month assessment included a 15-min free-play, 5-min structured task, and a 5-min snack time, and the free-play situation was analyzed separately. Otherwise, procedure was the same for all measurement timepoints.

Emotional Availability Scales

EA Scales consists of six scales, four of which measure separable aspects of caregiver behavior and were used in the present study: sensitivity, structuring, non-intrusiveness, and non-hostility. *Sensitivity* refers to parent's behaviors and emotions that create and maintain a healthy and positive connection with the child. A sensitive parent can meet the physical and psychological needs of the child with appropriate and well-timed responses. *Structuring* consists of a parent's behaviors that age-appropriately support the infant's autonomy and learning. A well structuring parent uses preventive structuring and guidance, remaining consistent when setting limits. *Non-intrusiveness* refers to parent's capacity to follow a child's lead in the play. A non-intrusive parent avoids interfering or interrupting the child physically or verbally, leaving enough space for the child to explore the environment. *Non-hostility* refers to the parent's ability to regulate their own negative emotions and to avoid expressing them towards the infant.

Each dimension has 7 subscales with a maximum total score of 29. In addition, a direct score for each dimension is given using a 7-point Likert-type scale describing the evaluator's overall view of the interaction. In the analyses of the current study, we used the direct scores, where the higher end of the scale refers to a healthier emotional connection between a mother and an infant. More detailed description of the scoring is presented in the EA manuscript (Biringen, 2008). The coding was done by two (8 months) or three (30 and 60 months) blinded and trained coders. Reliability was assessed for 10% of the video-recorded play situations. Reliability estimated with intraclass correlation coefficient was .80 for sensitivity, .72 for structuring, .85 for non-intrusiveness, and .70 for non-hostility for 8 months. For 30 months, intraclass correlation coefficient ranged from .83 to .91 for sensitivity, from .84 to .91 for structuring, from .84 to .90 for non-intrusiveness, and from .70 to .85 for non-hostility. For 60 months, intraclass correlation coefficient was .90 for sensitivity, .87 for structuring, .80 for non-intrusiveness, and .76 for non-hostility. Differences were negotiated between the coders and consensus ratings were used for subsequent analyses.

In previous literature, dimensions of parental EA are commonly studied either as independent qualities of parent-child interaction or as one EA composite, describing the degree of parent's emotional availability across all four dimensions (Biringen et al., 2014). In this study, we used confirmatory factor analysis to form one EA factor allowing all available EA data of the mothers to be included in the same model. Similar approach has been found useful in previous studies (Barone et al., 2018; Garvin et al., 2012; Kertes et al., 2009) as it decreases the number of variables and considers the collinearity between the scales.

Eye Tracking Procedure at 8, 30, and 60 Months

As described in Kataja et al. (2022), eye tracking assessments were conducted in a dimly lit room with EyeLink1000+ eye tracker (SR Research Ltd, Toronto, Ontario, Canada). During the assessment the child sat on the caregiver's lap at ages 8 and 30 months and alone on a chair at 60 months, at the distance of 50–70cm from the eye tracker and 65–85 cm from the screen. The researcher sat on a host computer which was next to participant but separated by a curtain to avoid interference. A five-point calibration procedure, with an audiovisual animation sequentially presented on the screen in five locations, was used before measurement. In the validation phase, the maximum error in gaze detection was set to 1.0 degrees. The calibration was repeated during measurement if the tracker failed to detect the eye (e.g., due to too much movement during the experiment). A sampling frequency of 500Hz was used.

We used an overlap paradigm (Peltola et al., 2008) to examine dwell times on centrally presented face (neutral, happy, fearful) or a scrambled face control stimulus upon presentation of a lateral distractor. The face stimuli were the same as those used in the study by Peltola et al. (2008). The distractor stimuli were vertically arranged black and white rectangles or circles (15.4° x 4.3°). At first, a picture of a neutral, happy, or fearful face or a non-face control stimulus was shown in the center of the screen for 1000ms. Then, a salient lateral distractor was presented at visual angle of 13° to the left or right side of the face or non-face stimulus for 3000 ms. The total duration of one trial was 4000 ms. The order of the central stimuli was semi-randomized so that the same stimulus was not presented more than three times in a row. The side of the lateral stimulus was selected randomly for each trial. To capture the attention of the child to the center of the screen before each trial, a brief animation was shown. The researcher monitored the child's gaze through the host computer and initiated a trial when the child's gaze was in the middle of the screen. For an illustration of the implementation of the overlap paradigm in this study, see Kataja et al. (2022).

The same paradigm was used at each measurement timepoint with the exception that the total number of trials and the type of the lateral distractor differed between the timepoints. At 8-month assessment, 48 trials (12 trials per condition) were presented, including photographs of two female faces with happy, fearful, and neutral expressions as well as a control stimulus created by phase-scrambling the (fearful) faces of the two females faces. After 24 trials, there was a small break, during which short animations were presented on the screen. At 30- and 60-month assessment, 24 trials (6 trials per condition) were presented, including only photographs of one female model posing neutral, happy, and fearful faces and a non-face control stimulus. The length of the assessment at 30 and 60 months had to be reduced as the children were also participating in other eye tracking experiments during the same visit (these will be reported elsewhere). The lateral distractor was also changed. At 8-month assessment, the distractor was a static geometric shape comprising of a black and white rectangle pattern or vertically arranged empty and filled circles. At 30-month and 60-month assessment, the distractors were the same geometric shaped, but the contrast polarity of the distractors was reversed during the presentation so that the distractor flashed at the frequency of 10Hz. Further, at 60 months, the flashing started only after the child directed attention towards the distractor. These manipulations were added to increase the saliency of the distractor for older children (Leppänen et al., 2018; Peltola et al., 2018).

Preprocessing of Eye Tracking Data

The xy coordinates of the participants' gaze position were stored and analyzed using custom MATLAB functions (Mathworks, Natick, MA; (Leppänen et al., 2015). To secure the quality of the trials retained in the analysis, the following a priori criteria were used based on studies using the same methodology and analytic approach (E. L. Kataja et al., 2019, 2020; E.-L. Kataja et al., 2022; Leppänen et al., 2015). Firstly, trials had to have sufficient looking at the central stimulus (>70%) during a time interval that started at the onset of the trial and extended to the end of the analysis period (i.e., gaze disengagement from the central to lateral stimulus or if a gaze disengagement was not observed, 1000 ms after the appearance of the lateral distractor). Secondly, trials had to have enough valid samples in the gaze data with no gaps greater than 200 ms. Thirdly, if the eye movement occurred during a period of missing or extrapolated gaze data (and the specific endpoint of dwell time could consequently not be determined), the trial was rejected. The proportion of valid trials per face condition at each timepoint are provided in the supplementary material.

Eye Tracking Variables

As a measure of engagement with faces, we used the duration of attention dwell time on the face stimulus (face or non-face pattern), determined as the time interval starting at the onset of the lateral stimulus and extending until the point of gaze shifted from the central face stimulus to the lateral stimulus or a time-out period of 1000 ms was reached. This approach is similar to that used in a prior study by Peltola et al. (2018), which also estimated mean dwell time for faces. The dwell times calculated this way are typically strongly correlated with the mean probability of missing gaze shifts from the central to the lateral stimulus, which have been used as an alternative measure of attention to faces in infants (Kataja et al., 2022; Pyykkö et al., 2019). For the analyses we separated attention dwell times for faces from dwell times for the scrambled face control stimuli (i.e., non-face patterns). Reliability estimates for dwell times for faces and non-faces at each timepoint are given in the supplementary material.

Statistical Analyses

To examine the reciprocal associations between engagement with faces and maternal emotional availability over time, a random intercept cross-lagged panel model (RI-CLPM) was fit to the data using Mplus version 8.6 software (Muthen & Muthen, 2017). RI-CLPM is a structural equation modelling approach, which differentiates the variance accounted for by time-invariant individual differences (between-subject effects) and dynamic changes (within-subject effects), therefore accounting for trait-like stability in the latent variables (Hamaker et al., 2015). Estimation of the random intercept for each variable allows for the evaluation of within-subject (or within-dyad) deviations from the latent average of the variable. In the context of this approach, the cross-lag associations represent the degree to which deviations in one variable (maternal emotional availability), predict the deviations on the other variable (child's face engagement) within-dyad and vice versa. Positive cross-lag associations indicate the level of deviations in one variable predict the level of deviations in the subsequent measurement of another variable within individuals, while negative cross-lags suggest an inverse predictive relationship. In other words, positive association would indicate lower within-subject deviations on one variable (stability) relate to lower within-subject deviations on another variable (stability), or the opposite of higher within-subject deviations on one variable (fluctuation) relating to higher within-subject deviations on the other variable (fluctuation). Negative association would signify higher within-subject deviations on one variable (fluctuation) relate to lower within-subject deviations on another variable (stability), or the opposite of lower within-subject deviations in one variable (stability) relating to higher within-subject deviations on the other variable (fluctuation).

The analyses were conducted with following steps. First, descriptive statistics were examined using IBM SPSS Statistics for Macintosh, Version 28.0. Second, confirmatory factor analyses were performed to ensure the mother-child interaction assessments and eye tracking data form expected factors, namely emotional availability (EA) and face engagement. We formed maternal EA factor for each of the timepoints based on the assumption that the four subscales of maternal EA (sensitivity, structuring, non-intrusiveness, and non-hostility) are reflecting overall mother-child interaction quality as one latent factor. For the eye tracking data, we used multilevel analysis. To our knowledge, a multilevel approach has not been used in previous eye tracking studies, although it can be useful to take the hierarchical structure of the data into account, in which the repeated trials are nested within a subject (cf. Snijders & Bosker, 1999). Compared to analysis using mean scores of trials, this approach has the following advantages: a) it can handle missing values at the intraindividual level using all available data, and b) it provides less biased estimates under maximum likelihood estimation (Mellalieu & Hanton, 2015). As mentioned above, each face condition (happy, neutral, fearful) consisted of several trials, which were coded in a long format. A multilevel model was conducted, with trials nested within individuals (i.e., level one representing the trial level and level two representing the individual level). The between-level variation in dwell times for each face condition were used to form one factor for each of the timepoints reflecting overall engagement with faces at the individual level. The dwell times for non-face stimuli (i.e., scrambled face) were left out from the main analysis. This decision was based on the finding that dwell times for different face conditions were strongly correlated (r_s between .884 - .982 at 8 months, .970 - .987 at 30 months, .883-.977 at 60 months), whereas correlations between faces and non-faces were weaker (r_s between .584 - .656 at 8 months, .783 - .846 at 30 months, .644 -.753 at 60 months). Similar findings have been reported based on different data (Peltola et al., 2018; Pyykkö et al., 2019; Vallorani et al., 2023). However, we performed additional analysis, where face factor was replaced with non-face data, allowing to evaluate whether observed effects are related to the stimuli category (face vs. non-face). Third, we tested measurement invariances for both factors to confirm same constructs were measured between timepoints. Finally, the random intercept cross-lagged panel model was computed including all the data of interest.

Final analyses were conducted with RI-CLPM instead of traditional cross-lagged panel model approach based on the notion that spurious effects may rise within the cross-lag associations if stable trait associations are not accounted for (Hamaker et al., 2015). Multilevel structure was applicable only for eye tracking data, and EA data were used only in the between-level analysis. Child's biological sex and mother's education were considered as relevant covariates in the additional analyses. Prenatal maternal distress (high/ low/ other) was considered as a covariate, but not included in the final analyses because the preliminary analyses showed no significant group differences for EA composite scores or mean dwell times for different face conditions. Since the sample size changed across timepoints, a missing value analysis was conducted to examine whether the missingness can be considered as Missing Completely at Random (MCAR). Little's (Little, 1988) MCAR test was utilized and showed that the data were MCAR (χ^2(24381) = 24090.110, *p* = .907). The parameters of the models were estimated with Full-Information Maximum Likelihood (FIML) estimation for dealing with missing data. The following criteria was used to assess model fit: the Root Mean Square Error of Approximation (RMSEA), the Comparative Fit Index (CFI) and the Standardized Root Mean Square Residual (SRMR). Good fit is indicated by RMSEA below .06, CFI above .95 and SRMR below .08 (Hu & Bentler, 1999).

Transparency and Openness

The data are not publicly available because of restrictions concerning data that contain information that could compromise the privacy of research participants. Requests for collaboration, including access to data supporting the findings of the current study, are considered by the Board of the FinnBrain Cohort Study. International and domestic collaboration is encouraged and inherent in the project. This study was not preregistered.

Results

The descriptive statistics for the main variables across the three timepoints are outlined in Tables 2 and 3. The one-factor structure was replicated for both face engagement and maternal EA at 8, 30, and 60 months, and all factor loadings were statistically significant. Factors loadings varying from .578 to .883 showed all four dimensions of maternal emotional availability had moderate or considerable influence on the EA factor. Non-hostility and sensitivity explained most of the variance in the factor across all timepoints, non-hostility having a slightly higher factor impact than sensitivity. As for the face engagement, factor loadings were all relatively high, varying from .930 to 1.0 between timepoints. For emotional availability factor, significant associations were seen between 8 and 30 months ($r = .461$, $p < .001$), between 8 and 60 months ($r = .512$, $p < .001$), and between 30 and 60 months ($r = .365$, $p < .001$). For face engagement factor, there was no association between 8 and 30 months, but a significant association was observed between 8 and 60 months ($r = .297$, $p < .01$) and between 30 and 60 months ($r = .452$, $p < .001$), consistent with Kataja et al. (2022). For more detailed description of the factors, see configural invariance model in the supplementary material.

Table 2

Descriptive Statistics for the Subscales of Maternal Emotional Availability (EA)

Child age	EA subscale	*M*	*SD*	Minimum	Maximum	*n*
8 months	Sensitivity	5.30	1.34	2	7	181
	Structuring	5.06	1.49	2	7	181
	Non-intrusiveness	5.58	1.50	1	7	181
	Non-hostility	6.10	1.03	3	7	181
30 months	Sensitivity	5.16	1.18	2	7	355
	Structuring	5.27	1.17	2.5	7	355
	Non-intrusiveness	5.8	1.22	2.5	7	355
	Non-hostility	6.33	.90	2.5	7	355
60 months	Sensitivity	5.37	.94	2.5	7	263
	Structuring	4.95	.93	2	7	263
	Non-intrusiveness	5.88	.77	3	7	263
	Non-hostility	6.28	.72	3.5	7	263

Table 3
Descriptive Statistics for the Attention Dwell Times (ms) for Faces

Child's age	Face condition	*M*	*SD*	Minimum	Maximum	*n*
	Neutral	634.29	193.34	214.67	1000	363
8 months	Happy	634.43	186.25	202.67	1000	363
	Fearful	736.81	186.93	188.75	1000	363
	Neutral	550.93	175.91	221.0	1000	333
30 months	Happy	491.35	165.53	209.2	1000	333
	Fearful	618.03	178.39	236.5	1000	333
	Neutral	605.35	195.51	195.0	1000	437
60 months	Happy	525.32	186.75	168.8	1000	437
	Fearful	629.75	183.33	194.0	1000	437

Measurement invariances across different timepoints were examined for both factors. Scalar invariance was achieved for face engagement and partial scalar invariance was achieved for maternal emotional availability (see supplementary material for detailed overall and comparative model fits). According to Steenkamp and Baumgartner (Steenkamp & Baumgartner, 1998), the achievement of full metric invariance means that the participants in the different timepoints responded to the items or tasks in a similar manner. Moreover, the achievement of full scalar invariance indicates that differences in the factor means can be comparable across timepoints. Although here full scalar invariance was not achieved for maternal EA factor, our aim in this study was not compare the factor means across timepoints, and partial scalar invariance can be regarded as sufficient for further random-intercept cross-lagged panel analysis.

Next, a random intercept cross-lagged panel model (RI-CLPM) was fit to the data. It is indicated that factor loadings should be invariant over time for meaningful comparison across factors (Mulder & Hamaker, 2021), and thus, the factor loadings for each indicator over time were constrained. Additionally, since not all the autoregressive paths in both maternal EA and face engagement factors were statistically significant in the first model, autoregressive paths were set to zero in the consecutive model. The models with and without autoregressive paths were compared using information criteria, and all the information criteria favored the latter model (AIC: 54984.818 vs. 54984.545; BIC = 55706.739 vs. 55680.911; saBIC: 55347.670 vs. 55334.552). The final model had a good fit ($\chi 2(188) = 264.269$, RMSEA = .010, CFI = .980, SRMR = .005, .081). The complete RI-CLPM, including the random intercepts and significant cross-lag associations is illustrated in Figure 1.

Between-Dyad Associations

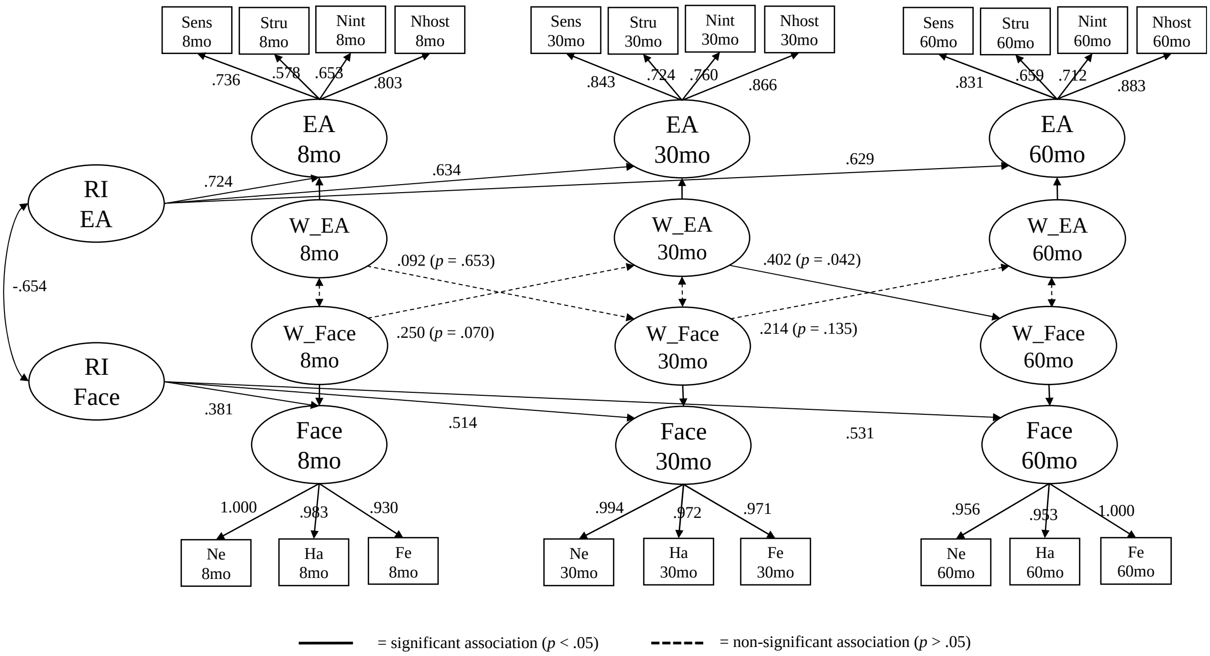
A significant negative association emerged for the between-dyad effects (random intercepts), indicating that higher maternal EA was associated with shorter dwell time for faces in children. For the maternal emotional availability random intercept, a significant positive association with the maternal EA factor was seen at each timepoint. For the face engagement random intercept, a significant positive association with the child's face engagement factor was also seen at each timepoint.

Within-Dyad Associations

Cross-lag associations showed that there was no significant cross-lag path between the maternal emotional availability and child's face engagement factors at 8- to 30-month assessments. However, a positive cross-lag path was found between the maternal emotional availability factor at 30-month assessment and the child's face engagement factor at 60-month assessment. A positive association implies that smaller within-dyad deviations (i.e., higher stability) in maternal emotional availability at 30 months were likely followed by smaller within-dyad deviations in a child's face engagement at 60 months. Cross-lag paths between child face engagement and maternal EA factors were not significant, but there was a non-significant positive association between 8- to 30-month assessments (p = .07) and 30- to 60-month assessments (p = .135). A positive trend suggests that smaller within-dyad deviations (i.e., higher stability) in a child's face engagement at 8 and 30 months may be related to smaller within-dyad deviations in maternal emotional availability in the following measurements.

Figure 1

A Random Intercept Cross-Lagged Panel Model



Note. RI = random intercept; EA = maternal emotional availability factor; Face = face engagement factor; W_EA = within-subject component of the EA factor; W_Face = within-subject component of the face engagement factor; mo = months; Sens = sensitivity; Stru = structuring; Nint = nonintrusiveness; Nhost = nonhostility; Ne = neutral; Ha = happy; Fe = fearful.

Covariate Model and Additional Analyses

Maternal education was significantly associated with the maternal emotional availability random intercept (r = .317, p < .001), while child's biological sex was not associated with either of the random intercepts (p > .05). Based on this observation, biological sex was excluded from the final analysis. After controlling for mother's education, we again found a negative association between the random intercepts (r = -.687, p = .049) and a significant cross-lag path between the maternal emotional availability and face engagement factors at 30- to 60-month assessments (r = .440, p = .019). The non-significant associations between the face engagement and maternal emotional availability factors at 8- to 30-month (r = .223, p = .105) and 30- to 60-month assessments (r = .255, p = .062) also remained similar.

In additional analyses, we tested a RI-CLPM where face engagement factor was replaced with dwell times for non-faces (“non-face engagement factor”). In this model, we did not observe association between the random intercepts or any significant (or trend-level) cross-lag associations between the maternal emotional availability and child’s dwell time for non-faces at the within-dyad level. For the full model, see supplementary material.

Discussion

In the current study, we used a random intercept cross-lagged panel model analysis to examine reciprocal associations between maternal emotional availability in mother-child interaction and children’s engagement with faces in a longitudinal general population sample from the FinnBrain birth cohort. We assessed mothers’ interaction in a free-play situation using Emotional Availability Scales at 8, 30, and 60 months of the child’s age and formed maternal emotional availability factor reflecting overall mother-child interaction quality. To assess children’s engagement with faces, we used eye tracking to measure attention dwell time for neutral, happy, and fearful facial expressions in the presence of a lateral distractor, and based on those measurements, formed a face engagement factor to examine overall face engagement at 8, 30, and 60 months of the child’s age. We expected to find associations between maternal emotional availability and child face engagement at the between-dyad level (random intercepts) and at the within-dyad level (deviations from the individual’s latent average). However, we did not have a clear hypothesis concerning the direction of the association.

Our confirmatory factor analysis replicated expected one-factor structure for both emotional availability and face engagement. All four dimensions of the maternal emotional availability were shown to reflect one latent factor, the quality of the emotional relationship between the dyad (Biringen et al., 2014), while it was indicated that maternal (non-)hostility and sensitivity were the most relevant dimensions of maternal emotional availability, possibly underlying the observed effects. For the face engagement factor, happy, neutral, and fearful facial expressions all had a considerable and relatively equal contribution, consistent with previous findings showing high correlations in dwell times for different facial expressions (Kataja et al., 2022; Peltola et al., 2018; Pyykkö et al., 2019; Vallorani et al., 2023) and the existence of a general face engagement factor in children.

We found that higher maternal emotional availability in mother-child interaction was associated with shorter attention dwell time for faces at the between-dyad level. At the within-dyad level, we found that mothers who showed more stability in their emotional availability (smaller deviations from their individual latent average) at the 30-month assessment had children who displayed more stability in their face engagement in the following assessment at 60 months. In addition, we found that children who had more stability in their face engagement at the 8- and 30-month assessments had mothers who showed more stability in their emotional availability in the following assessments, but these findings were non-significant.

The overall negative association between maternal emotional availability and face engagement between dyads is contradictory to the idea that higher quality of mother-child interaction is related to increased levels of face engagement in children. Our results seem to suggest that lower maternal emotional availability in interaction is associated with higher face engagement in children. This finding reflects the relationship between stable, possibly trait-like quality of a mother's interaction behavior and a child's baseline level of engagement with faces (in the presence of a distractor) across early to mid-childhood. As a potentially important related finding, a cross-sectional study that used a partly overlapping sample (Eskola et al., 2024) found that lower maternal emotional availability was related to the infant's difficulty in disengaging attention from fearful faces. Possibly in line with these findings, prior studies using similar eye-tracking paradigm have shown that elevated maternal depressive symptoms are associated with a lower likelihood of disengagement from fearful faces in infants (E. L. Kataja et al., 2020), while maternal anxiety symptoms have been associated with a lower likelihood of disengagement from fearful or angry faces (Fu & Pérez-Edgar, 2019; E. L. Kataja et al., 2019, 2020; Morales et al., 2017) or facial cues in general in girls during infancy (E. L. Kataja et al., 2019). Importantly, our finding aligns with a recent longitudinal study (Vallorani et al., 2023), which used the same analytic approach as the one used here and reported that, at baseline, higher levels of maternal anxiety were associated with greater attentional bias to emotional faces in children across the first two years of life.

There is no straightforward interpretation for the negative association between the emotional availability in mother-child interaction and child face engagement, but several possible mechanisms can be considered**.** One possibility is that there is a shared genetic background for social attention and some aspects of face-to-face interaction. This is suggested by findings showing that face engagement is genetic (Constantino et al., 2017; Portugal et al., 2024), infant and parental attention to facial configurations are associated (Aktar et al., 2022), and face engagement is related to prosocial behaviors (Bedford et al., 2015; Donohue et al., 2024; Eskola et al., 2023; Grossmann et al., 2018; Peltola et al., 2018). Another possibility is that the mother's interaction behaviors very early in development shape the child's attentiveness towards faces. For the dyad, faces hold an important role especially during infancy, as other means of communication and ways to explore the environment have not developed yet (Leppänen & Nelson, 2009). The first year of life is also known to be an important window for attachment formation, where the dyadic emotional regulation is a key component (Bernier et al., 2014; De Wolff & van Ijzendoorn, 1997). It could be argued that being exposed to less sensitive and relatively more hostile caregiving behaviors in the interaction could contribute to prolonged attention towards faces and difficulties in disengagement, for example, because the child may be seeking for reassurance of social cues and/or compensating for the lack of emotional connection in the interaction. Aside from such parent-to-child influences, the child's individual patterns of attention may also shape mother's interaction behaviors. This idea is supported by a study by Northrup and colleagues (Northrup et al., 2019) examining directional relations between infants' still-face response (i.e., change in affect and gaze from interaction to still-face) and parenting behaviors, which highlighted the influence of infants on their parents. It may be that infant's face engagement is relevant for early bonding and development of reciprocal relationship, as suggested by work using other types of methodologies (Beebe et al., 2016; Leong et al., 2017; Markova & Siposova, 2019). Naturally, all of these interpretations are tentative at this point and must be subjected to more confirmatory analyses in future studies.

At the within-dyad level, we did not see a cross-lag association between mother's emotional availability at 8 months and child face engagement at the 30-month assessment. However, there was a positive association between the maternal emotional availability at 30 months and face engagement at 60 months, which supports the proposition regarding the possible effects of mother-child interaction quality on the development of face engagement in children. In other words, it appears that a relative change (whether stability or fluctuation) in a mother's interaction behavior in toddlerhood predicts a similar pattern of change in the child's face engagement at 5 years. This interconnection might be related to the development of social attention, where at group-level, face bias is strong in infants, diminishes between infancy and toddlerhood, and strengthens again between 2.5 and 5 years (E.-L. Kataja et al., 2022). Thus, it is possible that mother's emotional availability in interaction does not influence the declining part of this U-shaped developmental trajectory, but it may shape the developmental processes that lead to the increase in the face bias between 30 and 60 months.

While our findings point to the role of emotional availability in mother-child interaction in shaping the development of social attention between toddlerhood and mid-childhood, we found no clear evidence for the influence of a child's individual characteristics on mother-child interaction. However, the non-significant cross-lag effects in our study suggest that stability in face engagement during infancy and toddlerhood might prospectively contribute to stability in the mother's interaction behaviors. More studies are needed to support this conclusion. If these effects are replicated in further studies, they would be in line with the idea of bidirectional relationship between the quality of mother's interaction behaviors and child's individual characteristics (Northrup et al., 2019; Paschall & Mastergeorge, 2016). However, evidence for bidirectionality was not found in a prior study that examined relationships between maternal anxiety and affect-biased attention (Vallorani et al., 2023).

Our findings diverge in some ways from those of a previous study that employed a comparable longitudinal approach, which found that fluctuations in maternal anxiety—a negative indicator of maternal caregiving—were prospectively associated with consistent attentional bias in children towards both happy and angry faces (Vallorani et al., 2023). Based on this finding, it was proposed that fluctuation in maternal symptoms may cause environmental uncertainty that could contribute to emerging stable attention patterns related to filtering of the environmental stimuli, possibly leading to biased processing of social information. Our findings, which are drawn from a different approach to maternal factors and development of social attention, point to a different type of interplay between these constructs, suggesting that fluctuation in the social environment (maternal emotional availability) would also lead to fluctuation in the child's attentiveness towards faces, although this may be age-specific. The stability of individual differences in attention to faces from infancy to mid-childhood seems to be fairly weak (E.-L. Kataja et al., 2022). However, the relative stability in the emotional availability in parent-child interaction in toddlerhood and face engagement in mid chilhood may merit further investigation for their associations with outcomes of social-emotional development.

Our random intercept cross-lagged panel analysis approach allowed us to examine reciprocal relations between maternal emotional availability in interaction and child face engagement across infancy, toddlerhood, and preschool age. The strength of this analytical approach is that it allows to assess changes within dyads over time in the context of stable trait associations, therefore adding relevant information to the field. To our knowledge, previous studies in this field have not used a similar longitudinal sample containing three developmentally different measurement timepoints. We also provided support for the hypothesized existence of a common maternal emotional availability and face engagement factors as well as additional analysis of the measurement invariances that supported the use of these factors and their comparability over time. After controlling for mother's education, our findings remained similar. However, given the exploratory nature of the current study and some trend-level associations in our data, the reported associations, and the interpretations we have offered for the findings should be considered preliminary and treated with caution.

It should be noted that although we were able to utilize random intercept cross-lagged panel model, our study is limited by the sample size and relatively low number of measurement points, which may influence the significance of the observed effects. These caveats notwithstanding, our results suggest that the relationship between child's engagement with faces and mother-child interaction may be more complex than previously thought. Importantly, in our additional analysis we did not find a similar relationship between maternal emotional availability and engagement with non-face stimuli, which could point to the face-specificity of our findings. Although this may suggest our findings are related to social attention, we acknowledge that difference in the results may also be affected by the difference in trial counts in the face and non-face conditions.

It is possible that some inconsistencies in the results of the studies linking parent-child interaction with child attention to social cues are related to methodological differences in the measurement of engagement with faces. In the current study, we examined attention towards faces in the presence of a distractor stimulus (i.e., the overlap paradigm; Peltola et al., 2008), which allowed us to examine prioritized attention to faces specifically. Studies using the same paradigm suggest a relative decrease in the saliency for faces versus nonsocial stimuli and increase in the likelihood of attention shifting after infancy is part of typical development (Kataja et al., 2022; Peltola et al., 2018; Xie et al., 2021). Together with the evidence linking maternal risk factors, such as anxiety and depressive symptoms, to difficulties in attention disengagement for facial configurations in children (Fu & Pérez-Edgar, 2019; E. L. Kataja et al., 2019, 2020; Morales et al., 2017), these findings support the idea that the ability to disengage attention away from faces is related to development from early to mid-childhood. It may be that studies underlining the effect of positive aspects of parent-child relationships on increased engagement with faces (e.g., Kammermeier & Paulus, 2021) have measured slightly different processes, also related to the development of social-emotional functioning. However, our study and the previous study by Kammermeier and Paulus (2021) are both limited by the use of static stimuli which may not fully capture the differences in social engagement in real-life settings. Libertus et al. (2017) studied face preference during the first 3 years of life for both static and dynamic face stimuli and found that face preference is stronger for static images during the first year, but stronger for dynamic stimuli during the second and third year. In addition, other studies have used mobile eye tracking to study child social attention during naturalistic play (Vallorani et al., 2022) or during parent-child interaction (Franchak et al., 2018; MacNeill et al., 2022), aiming to better capture the dynamic nature of social interactions which comprises of contingent responses between individuals. For future research, it might be interesting to assess the associations for parent-child interaction quality and child face engagement using more complex and realistic stimuli that might better capture face engagement in a child's normal environment.

In conclusion, we found a stable trait association between a mother's emotional availability in mother-child interaction and a child's engagement with faces. Additionally, we found evidence suggesting that stability in the mother's emotional availability is likely followed by stability in the child's face engagement over time, and possibly vice versa. Recognizing that stability or fluctuations occur within dyads and over the course of development implies that children's social-emotional development could be supported through focused interventions. However, further research and replication of these results, along with confirmatory testing of the proposed explanations, are necessary before drawing any implications for interventions from this research.

References

Aktar, E., Mandell, D. J., de Vente, W., Majdandžić, M., Oort, F. J., van Renswoude, D. R., Raijmakers, M. E. J., & Bögels, S. M. (2018). Parental negative emotions are related to behavioral and pupillary correlates of infants' attention to facial expressions of emotion. *Infant Behavior and Development*, *53*, 101–111. https://doi.org/10.1016/j.infbeh.2018.07.004

Aktar, E., Nimphy, C. A., Kret, M. E., Pérez-Edgar, K., Raijmakers, M. E. J., & 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*(3), 387–402. https://doi.org/10.1007/s10802-021-00848-3

Barone, L., Barone, V., Dellagiulia, A., & Lionetti, F. (2018). Testing an Attachment-Based Parenting Intervention-VIPP-FC/A in Adoptive Families with Post-institutionalized Children: Do Maternal Sensitivity and Genetic Markers Count? *Frontiers in Psychology*, *9*. https://www.frontiersin.org/articles/10.3389/fpsyg.2018.00156

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

Beebe, B., Messinger, D., Bahrick, L. E., Margolis, A., Buck, K. A., & Chen, H. (2016). A systems view of mother–infant face-to-face communication. *Developmental Psychology*, *52*(4), 556–571. https://doi.org/10.1037/a0040085.supp

Bernier, A., Matte-Gagné, C., Bélanger, M., & Whipple, N. (2014). Taking Stock of Two Decades of Attachment Transmission Gap: Broadening the Assessment of Maternal Behavior. *Child Development*, *85*(5), 1852–1865. https://doi.org/10.1111/cdev.12236

Biringen, Z. (2008). *Emotional Availability Scales (4th ed.)*. Boulder CO: International Center for Excellence in Emotional Availability. https://www.researchconnections.org/childcare/resources/26216

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

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

Constantino, J. N., Kennon-McGill, S., Weichselbaum, C., Marrus, N., Haider, A., Glowinski, A. L., Gillespie, S., Klaiman, C., Klin, A., & Jones, W. (2017). Infant viewing of social scenes is under genetic control and is atypical in autism. *Nature*, *547*(7663), 340–344. https://doi.org/10.1038/nature22999

Cox, J. L., Holden, J. M., & Sagovsky, R. (1987). Detection of Postnatal Depression: Development of the 10-item Edinburgh Postnatal Depression Scale. *The British Journal of Psychiatry*, *150*(6), 782–786. https://doi.org/10.1192/bjp.150.6.782

De Wolff, M. S., & van Ijzendoorn, M. H. (1997). Sensitivity and attachment: A meta-analysis on parental antecedents of infant attachment. *Child Development*, *68*(4), 571. https://doi.org/10.1111/j.1467-8624.1997.tb04218.x

Donohue, M. R., Camacho, M. C., Drake, J. E., Schwarzlose, R. F., Brady, R. G., Hoyniak, C. P., Hennefield, L., Wakschlag, L. S., Rogers, C. E., Barch, D. M., & Luby, J. (2024). Less attention to emotional faces is associated with low empathy and prosociality in 12-to 20-month old infants. *Infancy: The Official Journal of the International Society on Infant Studies*, *29*(2), 113–136. https://doi.org/10.1111/infa.12569

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

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*, 101900. https://doi.org/10.1016/j.infbeh.2023.101900

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*, 101838. https://doi.org/10.1016/j.infbeh.2023.101838

Forslund, T., Peltola, M. J., & Brocki, K. C. (2019). Disorganized attachment representations, externalizing behavior problems, and socioemotional competences in early school-age. *Attachment & Human Development*. http://www.tandfonline.com/doi/abs/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, and Allied Disciplines*, *55*(7), 793–801. https://doi.org/10.1111/jcpp.12181

Franchak, J. M., Kretch, K. S., & Adolph, K. E. (2018). See and be seen: Infant-caregiver social looking during locomotor free play. *Developmental Science*, *21*(4), e12626. https://doi.org/10.1111/desc.12626

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

Garvin, M. C., Tarullo, A. R., Ryzin, M. V., & 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

Grossmann, T., & Johnson, M. H. (2007). The development of the social brain in human infancy. *European Journal of Neuroscience*, *25*(4), 909–919. https://doi.org/10.1111/j.1460-9568.2007.05379.x

Grossmann, T., Missana, M., & Krol, K. M. (2018). The neurodevelopmental precursors of altruistic behavior in infancy. *PLOS Biology*, *16*(9), e2005281. https://doi.org/10.1371/journal.pbio.2005281

Gulley, L. D., Oppenheimer, C. W., & Hankin, B. L. (2014). Associations among negative parenting, attention bias to anger, and social anxiety among youth. *Developmental Psychology*, *50*(2), 577–585. https://doi.org/10.1037/A0033624

Hamaker, E. L., Kuiper, R. M., & Grasman, R. P. P. P. (2015). A critique of the cross-lagged panel model. *Psychological Methods*, *20*(1), 102–116. https://doi.org/10.1037/a0038889

Heck, A., Hock, A., White, H., Jubran, R., & Bhatt, R. S. (2016). The development of attention to dynamic facial emotions. *Journal of Experimental Child Psychology*, *147*, 100–110. https://doi.org/10.1016/j.jecp.2016.03.005

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

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

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. (2005). Subcortical Face Processing. *Nature Reviews Neuroscience*, *6*(10), 766–774. https://doi.org/10.1038/nrn1766

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 & Biobehavioral Reviews*, *50*, 169–179. https://doi.org/10.1016/j.neubiorev.2014.10.009

Jones, W., & Klin, A. (2013). Attention to eyes is present but in decline in 2–6-month-old infants later diagnosed with autism. *Nature*, *504*(7480), Article 7480. https://doi.org/10.1038/nature12715

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. (2021). *Maternal sensitivity and non-intrusiveness at 12 months predict attention to emotional facial expressions at 24 months: A cross-lagged panel approach*. https://doi.org/10.1111/sode.12561

Karlsson, L., Tolvanen, M., Scheinin, N. M., Uusitupa, H. M., 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), 15–16j. https://doi.org/10.1093/IJE/DYX173

Kataja, E. L., Karlsson, L., Leppänen, J. M., Pelto, J., Häikiö, T., Nolvi, S., Pesonen, H., Parsons, C. E., Hyönä, J., & Karlsson, H. (2020). Maternal Depressive Symptoms During the Pre- and Postnatal Periods and Infant Attention to Emotional Faces. *Child Development*, *91*(2), e475–e480. https://doi.org/10.1111/CDEV.13152

Kataja, E. L., Karlsson, L., Parsons, C. E., Pelto, J., Pesonen, H., Häikiö, T., Hyönä, J., Nolvi, S., Korja, R., & 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., Eskola, E., Pelto, J., Korja, R., Paija, S.-P., Nolvi, S., Häikiö, T., Karlsson, L., Karlsson, H., & 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*, *58*(12), 2264–2274. https://doi.org/10.1037/dev0001432

Kelly, D. J., Duarte, S., Meary, D., Bindemann, M., & Pascalis, O. (2019). Infants rapidly detect human faces in complex naturalistic visual scenes. *Developmental Science*, *22*(6), e12829. https://doi.org/10.1111/desc.12829

Kertes, D. A., Donzella, B., Talge, N. M., Garvin, M. C., Van Ryzin, M. J., & Gunnar, M. R. (2009). Inhibited temperament and parent emotional availability differentially predict young children's cortisol responses to novel social and nonsocial events. *Developmental Psychobiology*, *51*(7), 521–532. https://doi.org/10.1002/dev.20390

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 & Biobehavioral Reviews*, *50*, 189–203. https://doi.org/10.1016/J.NEUBIOREV.2014.10.006

Leong, V., Byrne, E., Clackson, K., Georgieva, S., Lam, S., & Wass, S. (2017). Speaker Gaze Increases Information Coupling Between Infant and Adult Brains. *Proceedings of the National Academy of Sciences*, *114*(50), Article 50. https://doi.org/10.1073/pnas.1702493114

Leppänen, J. M. (2016). Using Eye Tracking to Understand Infants' Attentional Bias for Faces. *Child Development Perspectives*, *10*(3), 161–165. https://doi.org/10.1111/cdep.12180

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), e0197424. 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/FIGURES/5

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

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*. https://www.frontiersin.org/articles/10.3389/fpsyg.2017.01976

Lindblom, J., Peltola, M. J., Vänskä, M., Hietanen, J. K., Laakso, A., Tiitinen, A., Tulppala, M., & Punamäki, R. L. (2015). Early family system types predict children's emotional attention biases at school age: *Http://Dx.Doi.Org/10.1177/0165025415620856*, *41*(2), 245–256. https://doi.org/10.1177/0165025415620856

Little, R. J. A. (1988). A Test of Missing Completely at Random for Multivariate Data with Missing Values. *Journal of the American Statistical Association*, *83*(404), 1198–1202. https://doi.org/10.2307/2290157

MacNeill, L. A., Fu, X., Buss, K. A., & Pérez-Edgar, K. (2022). Do you see what I mean?: Using mobile eye tracking to capture parent-child dynamics in the context of anxiety risk. *Development and Psychopathology*, *34*(3), 997–1012. https://doi.org/10.1017/S0954579420001601

Markova, G., & Siposova, B. (2019). The role of oxytocin in early mother-infant interactions: Variations in maternal affect attunement. *Infant Behavior and Development*, *55*, 58–68. https://doi.org/10.1016/j.infbeh.2019.03.003

Mastorakos, T., & Scott, K. L. (2019). Attention biases and social-emotional development in preschool-aged children who have been exposed to domestic violence. *Child Abuse & Neglect*, *89*, 78–86. https://doi.org/10.1016/J.CHIABU.2019.01.001

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

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

Mulder, J. D., & Hamaker, E. L. (2021). Three Extensions of the Random Intercept Cross-Lagged Panel Model. *Structural Equation Modeling: A Multidisciplinary Journal*, *28*(4), 638–648. https://doi.org/10.1080/10705511.2020.1784738

Muthen, L. K., & Muthen, B. (2017). *Mplus Version 8 User's Guide*. Muthen & Muthen.

Nelson, C. A., & Dolgin, K. G. (1985). The Generalized Discrimination of Facial Expressions by Seven-Month-Old Infants. *Child Development*, *56*(1), 58–61. https://doi.org/10.2307/1130173

Northrup, J. B., Ridley, J., Foley, K., Moses-Kolko, E. L., Keenan, K., & Hipwell, A. E. (2019). A transactional model of infant still-face response and maternal behavior during the first year. *Infancy*, *24*(5), 787–806. https://doi.org/10.1111/infa.12306

Paschall, K. W., & Mastergeorge, A. M. (2016). A review of 25 years of research in bidirectionality in parent–child relationships: An examination of methodological approaches. *International Journal of Behavioral Development*, *40*(5), 442–451. https://doi.org/10.1177/0165025415607379

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*, *86*(5), 1321–1332. https://doi.org/10.1111/CDEV.12380

Peltola, M. J., Hietanen, J. K., Forssman, L., & Leppänen, J. M. (2013). The emergence and stability of the attentional bias to fearful faces in infancy. *Infancy*, *18*(6), 905–926. https://doi.org/10.1111/INFA.12013

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 and 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*, *21*(6), e12687. https://doi.org/10.1111/desc.12687

Pollak, S. D. (2015). Multilevel developmental approaches to understanding the effects of child maltreatment: Recent advances and future challenges. *Development and Psychopathology*, *27*(4pt2), 1387–1397. https://doi.org/10.1017/S0954579415000826

Portugal, A. M., Viktorsson, C., Taylor, M. J., Mason, L., Tammimies, K., Ronald, A., & Falck-Ytter, T. (2024). Infants' looking preferences for social versus non-social objects reflect genetic variation. *Nature Human Behaviour*, *8*(1), Article 1. https://doi.org/10.1038/s41562-023-01764-w

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), Article 1. https://doi.org/10.1038/s41598-019-51034-x

Reider, L. B., Bierstedt, L., Burris, J. L., Vallorani, A., Gunther, K. E., Buss, K. A., Pérez-Edgar, K., Field, A. P., & LoBue, V. (2022). Developmental patterns of affective attention across the first 2 years of life. *Child Development*, *93*(6), e607–e621. https://doi.org/10.1111/cdev.13831

Reynolds, G. D., & Roth, K. C. (2018). The Development of Attentional Biases for Faces in Infancy: A Developmental Systems Perspective. *Frontiers in Psychology*, *9*. https://www.frontiersin.org/articles/10.3389/fpsyg.2018.00222

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

Saunders, H., Kraus, A., Barone, L., & Biringen, Z. (2015). Emotional availability: Theory, research, and intervention. *Frontiers in Psychology*, *6*(JUL), 1069. https://doi.org/10.3389/FPSYG.2015.01069/BIBTEX

Snijders, T. A. B. (1999). *Multilevel analysis: An introduction to basic and advanced multilevel modeling*. SAGE.

Steenkamp, J.-B. E. M., & Baumgartner, H. (1998). Assessing Measurement Invariance in Cross-National Consumer Research. *Journal of Consumer Research*, *25*(1), 78–90. https://doi.org/10.1086/209528

Taylor-Colls, S., & Pasco Fearon, R. M. (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

Vallorani, A., Brown, K. M., Fu, X., Gunther, K. E., MacNeill, L. A., Ermanni, B., Hallquist, M. N., & Pérez-Edgar, K. (2022). Relations between social attention, expressed positive affect and behavioral inhibition during play. *Developmental Psychology*, *58*(11), 2036–2048. https://doi.org/10.1037/dev0001412

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), Article 1. https://doi.org/10.1038/s41598-021-81119-5

Vallorani, A., Gunther, K. E., Anaya, B., Burris, J. L., Field, A. P., LoBue, V., Buss, K. A., & 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. https://doi.org/10.1037/dev0001479.supp

Xie, W., Leppänen, J. M., Kane-Grade, F. E., & Nelson, C. A. (2021). Converging neural and behavioral evidence for a rapid, generalized response to threat-related facial expressions in 3-year-old children. *NeuroImage*, *229*, 117732. https://doi.org/10.1016/j.neuroimage.2021.117732