Attention Biases for Emotional Facial Expressions During a Free Viewing Task Increase between 2.5 and 5 Years of Age

Abstract

The normative, developmental changes in affect-biased attention during the preschool years are largely unknown. To investigate the attention bias for emotional versus neutral faces, an eye-tracking measurement and free viewing of paired pictures of facial expressions (i.e., happy, fearful, sad, angry faces) and non-face pictures with neutral faces were conducted with 367 children participating in a Finnish cohort study at the age of 2.5 years and with 477 children at the age of 5 years with 216 of which having follow-up measurements. We found an attention-orienting bias for happy and fearful faces versus neutral faces at both age points. An attention-orienting bias for sad faces emerged between 2.5 and 5 years. In addition, there were significant biases in sustained attention toward happy, fearful, sad and angry faces versus neutral faces with a bias in sustained attention for fearful faces being the strongest. All biases in sustained attention increased between 2.5 and 5 years of age. Moderate correlations in saccadic latencies were found between 2.5 and 5 years. In conclusion, attention biases for emotional facial expressions seem to be age-specific and specific for the attentional sub-component. This implies that future studies on affect-biased attention during the preschool years should use small age ranges and cover multiple subcomponents of attention.

Keywords: children, face processing, emotion, attention bias, development

Public significance statement

This study suggests that 2.5- and 5-year-old-children show an attentional preference for emotional faces over neutral faces in a free-viewing task. These attention biases for emotional faces increase between 2.5 and 5 years of age. The characterization of the typical development of emotional attention biases is important, as the emotional attention biases seem to have reciprocal connections to social-emotional well-being.

Introduction

Affect-biased attention can be defined as a perceptual preference for an object based on its affective salience (Todd et al., 2012). This selective attention process, which favors certain emotional categories, influences information processing right after birth (Farroni et al., 2007; Johnson et al., 2015) and undergoes rapid changes during infancy (Leppänen & Nelson, 2012). Affect-biased attention seems to have connections to social-emotional development (Leppänen & Nelson, 2012; Morales et al., 2016). Previous studies have focused on infancy and children older than 4 years (see reviews Dudeney et al., 2015; Fu & Pérez-Edgar, 2019). However, the developmental changes in affect-biased attention during toddlerhood and early pre-school years are largely unknown and follow-up studies are scarce (Fu & Pérez-Edgar, 2019; Morales et al., 2016). The present study explores the development of affect-biased attention in attention orienting and sustained attention from toddlerhood to preschool years using eye tracking measurement and free viewing of paired emotional facial expressions.

According to recent theories, the relation between affect-biased attention and socioemotional functioning may be reciprocal (Morales et al., 2016; Van Bockstaele et al., 2014). Some emotional attention biases seem to be normative, such as a bias in attentional disengagement from happy faces over fearful faces among newborn infants (Farroni et al., 2007) and an attention bias for fearful faces over happy and neutral faces emerging between 5 and 7 months of age (Peltola et al., 2009; Yrttiaho et al., 2014). These age-typical attention biases may support typical development (Morales et al., 2016), as, for example, a higher attention bias for fearful faces at 7 months of age has been related to secure attachment with a caregiver at 14 months (Peltola et al., 2015). Some attention biases are seen both among children and adults, such as attention bias for negative and especially threatening information (Lagattuta & Kramer, 2017; LoBue & DeLoache, 2008; Öhman & Mineka, 2001). However, it is well established that the variance in emotional attention biases is related to adverse developmental outcomes or symptoms of psychopathology, as, for example, a higher attention toward threat has been related to anxiety symptoms in adults, adolescents and children older than 4 years (Bar-Haim et al., 2007; Dudeney et al., 2015). In this context, it is crucial to understand typical, age-related changes in affect-biased attention.

Emotional attention biases manifest in different subcomponents of attention (Amso & Scerif, 2015; Morales et al., 2016). Three different brain networks involved in visual attention have been described: (1) alerting network that increases receptivity to targets, (2) orienting network that improves the priority of selected targets and (3) executive network that is involved in resolving competing responses to targets (Posner et al., 2014). In terms of temporal dimension, attention biases range from transient initial alerting to the target to sustained attention over prolonged periods (Amso & Scerif, 2015). Attention can also be divided into externally driven attention, i.e., exogenous attention, and internally driven attention, i.e., endogenous attention (see [Wass et al., 2018]). Endogenous, voluntary attention control is thought to mature during childhood and it is hard to measure during infancy (Posner et al., 2014; Wass, 2018).

Several tasks have been created to study biases across different components of attention in laboratory settings. One of the most used tasks is the dot-probe task (Fu & Pérez-Edgar, 2019; MacLeod et al., 1986). In the seminal study by MacLeod et al (1986) a pair of words, one threat-related and another with neutral content, was shown on the computer screen with a target probe subsequently appearing at the location of either of the words, and with participants indicating the location of the probe. Shorter probe detection latencies preceded by certain stimuli are interpreted as an attention bias to those stimuli (Fu & Pérez-Edgar, 2019). The dot-probe task is created to measure attention orienting (Fu & Pérez-Edgar, 2019; MacLeod et al., 1986). Additionally, as the task measures reactions to an appearing stimulus, it reflects exogenous, externally driven attention. Despite being in wide use, the dot-probe task has shown to have poor test-retest reliability and internal consistency (see the review by Fu & Pérez-Edgar, 2019).

Another task widely used among infants and children is the overlap task, in which the target stimulus is presented at the center of the screen and an overlapping lateral stimulus to the left or right of the target stimulus (Aslin & Salapatek, 1975; Peltola et al., 2008; Saslow, 1967). Although the task has been created to measure attention disengagement and orienting using the reaction time and/or the probability of a gaze shift from the central stimulus to the lateral distractor as the indices, also total dwell times have been analyzed as a measure of sustained attention. Also, the overlap task reflects exogenous attention.

To our knowledge, there are only two previous studies on emotional attention biases in children between 2 and 5 years that have used free viewing of paired-face stimuli (Dodd et al., 2020; Lagattuta & Kramer, 2017) that enables the measurement of endogenous, internally driven attention and attention biases both in attention orienting and sustained attention. Lagattuta and Kramer (2017) paired happy faces with negative facial expressions and found both an attention-orienting bias and a bias in sustained attention for negative facial expressions among 4-year-old children. Interestingly, the negative bias in sustained attention was lower among 10-year-old children and adults. They also found an attention-orienting bias for happy versus neutral faces. Furthermore, Dodd et al. (2020) found a bias in sustained attention for angry and happy faces when paired with neutral faces among 3–4-year-old children.

Field and Lester (2010) have proposed three competing models on how information processing biases, including attention biases, manifest during the development and how this development is related to atypical attention biases related to, for example, anxiety symptoms. According to the integral bias model, attention biases are innate and do not change during the development. Other individual factors, such as anxiety, are related to attention biases, but the relation stays stable over the course of development. According to the moderation model, attention biases are present in the early childhood but diminish over time in typical development. In atypical development, for example, when a child has anxiety symptoms, the attention biases remain high over the course of the development. Finally, according to the acquisition model, the development of attention biases is linked with the cognitive, emotional and social development and the biases may emerge at certain point of the development. Individual factors, such as anxiety, interact with the attention biases. In addition, Field and Lester (2010) shortly mention the possibility of the fourth model, a hybrid model, that was expanded by Morales et al. (2016). The hybrid model assumes that innate attention biases are based on individual factors and factors intrinsic and extrinsic to the individual moderate the biases during the development.

Some previous cross-sectional studies have supported the integral bias model, as they reported no effect of age on affect-biased attention between children from 4 to 24 months (Morales et al., 2017; Pérez-Edgar et al., 2017) or from 9 to 48 months (Burris et al., 2017). Longitudinal study designs, in turn, have supported the acquisition model, as they have found changes in emotional attention biases and low individual stability from infancy to toddlerhood (Nakagawa & Sukigara, 2012; Peltola et al., 2018). For example, a bias in attentional disengagement from fearful faces over neutral faces seems to wane between 7 and 24 months (Peltola et al., 2018), and a bias for angry versus happy faces seems to emerge between 12 and 36 months (Leppänen et al., 2018). The correlations between the measurements were low for attention to neutral, happy and fearful facial expressions. There are at least two possible interpretations for the low correlations: they may reflect either low stability in attention patterns between infancy and toddlerhood (Nakagawa & Sukigara, 2012; Peltola et al., 2018) or low test-retest reliability in eye-tracking measures among infants (Cousijn et al., 2017; Hessels et al., 2016). To our knowledge, the present study is the first one to investigate developmental changes in affect-biased attention from toddlerhood to the preschool years.

To further the understanding of the attention biases for different emotional facial expressions during early childhood, the aim of this study was to explore the affect-biased attention among toddlers at 2.5 years, and to follow up their development during their preschool years (at 5 years) by using a longitudinal study design. We used free viewing of paired-face pictures (i.e., neutral faces paired with happy/sad/angry/fearful face/non-face). We used relatively long trial durations (4000 / 5000 ms) to investigate different aspects of gaze behavior reflecting different subcomponents of attention: attention orienting and sustained attention. Our research questions were:

1. Do emotional facial expressions influence attention orienting at the onset of the trial?
2. Do emotional facial expressions influence sustained attention during the trial?
3. How stable are the attention biases between 2.5 and 5 years?

Materials and Methods

Participants and Study Design

The participants (2.5 y, *n* = 367; 5 y, *n* = 477, follow-ups, *n* = 216) belong to the larger FinnBrain Birth Cohort Study (n = 3808, www.finnbrain.fi) that examines environmental and genetic 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, when the mother and their spouse visited the health care clinic for the first trimester ultrasound. The study protocols of 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.

This study is a part of the Child Development and Parental Functioning Lab visits at the age of 8 months, corrected for prematurity, and again at 2.5 years, from birth, and 5 years, from birth. We invited families that belong to a subgroup of the main Cohort selected based on including groups of mothers reporting high levels of prenatal psychological distress (i.e., depressive, anxiety, and pregnancy-related anxiety symptoms) and mothers reporting no prenatal psychological distress (for a more detailed description see [Karlsson et al., 2018]), but also other actively participating families. The study visits included eye-tracking measurements, measurements of temperament, cognitive functions and mother-infant interaction. The background information of the participants is presented in Table 1 and the recruitment process and data loss are described in Figure 1. The present substudy was not preregistered.

Materials

Eye Tracking of Emotional Faces

The eye-tracking measurements were conducted in a dimly lit room with the participants being at a distance of 50–70 cm from the tracker (Desktop Mount, EyeLink1000+. SR Research Ltd, Toronto, Ontario, Canada). The screen was placed 15 cm behind the tracker. The children were seated on their parent's lap at 2.5 years and alone on the chair at 5 years while the parent was sitting closely behind the child. A sticker placed on the child's forehead was used to compensate for head movements. At 2.5 years of age, several participants first refused to take the sticker or tried to remove it during the measurement. Therefore, we tried to help the participant to feel comfortable using many small tricks (e.g., introducing the sticker in the waiting room with researchers and parents wearing stickers). At 5 years, almost all participants agreed to put the sticker on their forehead. The experiment was conducted by a researcher located behind a curtain. At both age points, the researchers avoided talking during the trials, but at the 2.5-year measurement, they might use short phrases (e.g., Hey, what's there? Do you see that? Good job!) to encourage a toddler to continue looking at the screen. The researcher conducted a 5-point calibration and validation routine before the experiment. The tracker recorded the x- and y-coordinates of the gaze location on the screen at a frequency of 500 Hz.

Free viewing of emotional face pairs. At 2.5 and 5 years, free viewing of pairs of face images (12.7° x 15.4°) with one neutral and one emotional face or non-face stimulus was conducted (Figure 2). The task consisted of 36 trials presenting face pairs for 5000 ms at 2.5 years. At 5 years, the same face pairs were presented only for 4000 ms and only 2 trials of non-face pattern were presented to shorten the task, as the children's interest in the task seemed to decrease during the task at 2.5 years. More specifically, at 2.5 years, on average 281 participants provided valid data per trial for the first 5 and only 199 participants for the last 5 trials, respectively. The researcher started the trial when a child was looking at the pre-trial, audio-visual animation on the center of the screen with a maximum of 2° difference between the center of the animation and the estimated gaze location. The face stimuli were color images of a woman posing with neutral, happy, sad, fearful and angry facial expressions adopted from the NimStim set (pictures of "Actor 1"; [Tottenham et al., 2009]). The non-face pattern was created by randomizing the phase spectrum of the face stimuli and by cropping the resulting picture to the outline of the face so that this control picture was matched for low-level psychophysical properties with the face stimuli (following the procedure described by [Halit et al., 2004]). Each pair (i.e., neutral–happy, neutral–sad, neutral–fearful, neutral–angry, neutral–neutral and neutral–non-face) was presented 6 times in a semi-random order so that the same pair was presented no more than 2 times in a row.

The researcher terminated the experiment if a child verbally or behaviorally indicated a willingness to stop despite the researcher's or the parent's kind encouragement to continue. The experiment was also terminated if a child became seemingly inattentive or upset.

Gaze Acquisition and Raw Data Processing

The 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 2). 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. The mean number of valid trials in the emotional face conditions was 4.86 of 6 trials at 2.5 years and 5.61 of 6 trials at 5 years (Table 2). The trial number dependency for all main variables concerning non-neutral faces is presented in Supplemental Figures 5–7. 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 were calculated using trial-by-trial data and they were low at 2.5 years (r = -.12) and at 5 years (r = -.15). Furthermore, as the trial duration varied between the two age points, only the first 4000 ms were included in the analyses.

Statistical Analyses

Attention orienting: Latency to First Fixation on Non-Neutral Faces

To estimate the mean *latency to first fixation* on non-neutral faces, the data consisting of trials, where the first fixation happened between 150 ms and 1000 ms and was directed to the non-neutral face, were analyzed using a linear mixed model with the following structure:

Model 1: 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 evaluate the correlations of the latencies to first fixation between the age points and faces, the mean latency to first fixation (over 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.

Attention-orienting Bias

We used the probability of 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 2: 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 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.

Bias in Sustained Attention

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

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 3: AttentionBias ~ Face + Age + Face x Age + (Age | Child)

The number of valid trials was controlled in the analyses.

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, and, after which Pearson correlations for these mean biases were calculated.

In each of the above models, latent individual quantities, latency to 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, so they were therefore not used.

For each of the three above mentioned cases, the corresponding sex-wise analyses were made using Models 1, 2 and 3 with the main effect of sex and its interactions added among the fixed effects, i.e., the fixed effects of the models were:

$$Sex + (Face + Age + Face \times Age) + Sex \times (Face + Age + Face \times Age)$$

All the analyses were performed in R 4.0.5 (R Core Team, 2021), and the mixed models were fitted using the R package lme4 (Bates et al., 2015).

Calculation of the reliability estimates for each face

Latency to first fixation

The latency times of the first fixation of the trials where the first fixation was on the non-neutral face were examined (Table 4). Only the children who fixated first at the non-neutral face at least three times were included in the calculations. This was because there were at maximum six trials for each face but in about half of the cases children fixated first at the neutral face, when the latency to first fixation was not defined. The data used in the calculations thus consisted of three variables consisting of the latency times of the first three trials where the child fixated first at the non-neutral face. The first variable corresponded the first trial where the child fixated on the non-neutral face. The second variable corresponded the second trial where the child fixated on the non-neutral face. The third variable corresponded the third trial where the child fixated on the non-neutral face. Cronbach's alpha was calculated based on these three variables.

- The split half reliabilities were calculated as follows:
    1. The 1st and 3rd variable formed the first half, and the 2nd variable was the second half.

2. Latency for the first half was calculated as the mean of the 1st and 3rd latencies and the latency for the second half was the 2nd latency.
3. Pearson correlation coefficient (r) between these two latencies were calculated.
4. Split-half reliability was estimated by using Spearman-Brown formula: $r_{sh} = 2r / (1 + r)$.

Attention-orienting bias

The reliability estimates for the attention-orienting bias were calculated by treating the binary data as numbers 0 (= first fixation on the neutral face) and 1 (= first fixation on the non-neutral face; Table 4). Only the children from whom all six trials (for the examined face) were available were included in the calculations. The data used in the calculations thus consisted of six variables consisting of zeros and ones. The first variable corresponded the first appearance of the face for a child. The second variable corresponded the second appearance of the face for a child, etc. Cronbach's alpha was calculated based on these six variables.

The split half reliabilities were calculated as follows:

1. The 1st, 3rd and 5th variable formed the first half, and the 2nd, 4th and 6th variable formed the second half.
2. Attention-orienting bias was calculated for each child for *each half* as: bias = mean of the three variables
3. Pearson correlation coefficient (r) between these two bias variables (a bias variable for each half) was calculated.
4. Split-half reliability was estimated by using Spearman-Brown formula: $r_{sh} = 2r / (1 + r)$. Split-half reliability estimate r_{sh} can have values less than -1 if $r < -1/3$

Bias in sustained attention

Reliability estimates for bias in sustained attention were calculated exactly as for attention-orienting bias except that now the six variables consisted of the *AttentionBias* values (real numbers between -1 and 1) defined in Statistical analysis section (Table 4).

Calculation of the reliability estimates across faces

The reliability estimates for bias in sustained attention and latency to first fixation were calculated also across all faces (Table 4). They were calculated in a similar manner as the face-wise estimates (described above) with a few exceptions:

Latency to first fixation

Only the children who fixated first at the non-neutral face at least 12 times were included in the calculations. When calculating the split-half reliabilities, 1st, 3rd,…, 11th trials formed the first half and 2nd, 4th,…, 12th trials formed the second half.

Bias in sustained attention

Only the children from whom all 30 trials (5 faces x 6 trials) at 2.5 years or 26 trials (4 faces x 6 trials + 2 trials for non-face) at 5 years were available. The sample size for 2.5 years age point was thus only 47 and explains the rather high p value for split-half reliability. When calculating the split-half reliabilities, 1st, 3rd,…, 29th/26th trials formed the first half and 2nd, 4th,…, 30th/26th trials formed the second half.

Data Availability

Data available for researchers on request due to privacy and ethical restrictions.

Results

Descriptive Statistics of the Fixation Patterns

The temporal pattern of fixation on each emotional face is presented in Figure 3. The spatial distributions of gaze across all face pairs are presented in Figure 4.

Attention Orienting: Latency to First Fixation on Non-neutral Faces

Estimated mean latencies to first fixation on non-neutral faces from Model 1 are presented in Figure 5 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 first fixation for happy, sad, angry or fearful faces or non-face pictures within either age group (Figure 5). However, the latencies to first fixation shortened statistically significantly between 2.5 and 5 years in the conditions of happy, sad, angry and fearful faces (Table 5). All statistically significant findings remained as such after controlling for the effects of the number of the valid trials. Interestingly, at the age of 5 years, girls showed shorter latencies to first fixation for angry faces compared to boys (Supplemental Figure 1).

Attention-Orienting Bias: Probability of First Fixation to a Non-neutral Face

The estimated probabilities of first fixation to a non-neutral face from Model 2 are presented in Figure 6. At 2.5 years of age, the probability of first fixation to a happy or a fearful face was higher than to a neutral face (Table 3). At 5 years of age, the probability of first fixation to a happy, sad and fearful face was higher than to a neutral face (Table 3). 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 (Table 3). In addition, the probability of first fixation to a non-face picture was lower than to a neutral face at both age points indicating attention-orienting bias for neutral faces compared to non-face patterns. All statistically significant findings remained as such after controlling for the effects of the number of the valid trials. Based on Model 2, there was a statistically significant increase in the probability to first fixate on a happy, sad and fearful face between 2.5 years and 5 years (Table 5). The probability of first fixation to a neutral face was higher than to the non-face picture in both age groups indicating an attention-orienting bias for faces (Table 3). The attention-orienting bias for faces increased between 2.5 and 5 years (Table 5). We found no statistically significant difference between boys and girls in the probability to first fixate a non-neutral face in either age group (supplemental Figure 1).

Bias in Sustained Attention: A Bias in Total Fixation Time for Non-neutral Faces

Bias in sustained attention was estimated based on total fixation times for non-neutral faces compared to total fixation times for neutral faces. Based on Model 3, 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. 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 3 and 4, Figure 7). We found no statistically significant difference between a bias in sustained attention for sad and angry faces (Table 6). There was also a statistically significant bias in sustained attention for the neutral face versus the non-face picture (Table 3). At the age of 5 years, the bias in sustained attention for fearful faces was still the highest and we found no differences between the biases for happy, sad and angry faces (Table 3 and 4, Figure 7). Also, the bias in sustained attention for neutral faces versus non-face patterns was no longer seen at 5 years (Table 3). The bias in sustained attention for all non-neutral faces increased statistically significantly between 2.5 and 5 years (Table 5). At 5 years, we found no statistically significant bias in sustained attention for neutral faces versus the non-face picture (Table 3). All statistically significant findings remained as such after controlling for the effects of the number of the valid trials. We found no statistically significant differences in the bias in sustained attention between girls and boys at either age point (Supplemental Figure 1).

Correlations between 2.5 and 5 years

There were small but statistically significant correlations ($r = .15 – .31$) between the age points in the latencies to first fixation for happy, sad, angry and fearful faces (Table 7). These small correlations were not only between the same stimulus types, 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 first fixation of all trials (0.36 [0.24; 0.47], $p < .0001$). We found no significant correlations between the 2.5- and 5-year measurements of the probability to first fixate to any non-neutral facial expression (Table 8). 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 ($r = .25$, $p = .001$) but no other significant correlations (Table 9).

Discussion

In this study, we investigated emotional attention biases during early childhood using eye-tracking measurements and free viewing of paired face pictures. 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. In addition, we found an attention-orienting bias for neutral faces versus non-face patterns among 2.5- and 5-year-olds but a bias in sustained attention for neutral faces vs. non-faces only among 2.5-year-olds.

As hypothesized, an attention bias for happy versus neutral faces was detected in attention orienting and sustained attention both among 2.5- and 5-year-olds. These results are in line with some previous studies among 3–5-year-old children 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 paradigm (Peltola et al., 2018), but in contrast to some other studies using the dot-probe task (Pérez-Edgar et al., 2011) or the overlap paradigm (Morales et al., 2017; Nakagawa & Sukigara, 2012). The sample sizes of the present study (n = 367–477) are larger than the sample sizes of the previous studies, which varied from 26 to 187 participants. Taking our findings and previous findings together, it seems that the nature of the attention biases for happy faces versus fearful or neutral faces changes during the first two years (Farroni et al., 2007; Peltola et al., 2009, 2018). More precisely, newborn infants may demonstrate increased attention to happy faces over fearful faces, but as a finding from a single study this should be interpreted with caution (Farroni et al., 2007). By the age of 7–8 months, infants show a higher attention bias to fearful than happy faces (Kataja et al., 2020; Leppänen et al., 2018; Peltola et al., 2009, 2008). According to our findings, the bias in sustained attention for fearful versus neutral faces is still higher than the bias for happy faces at 2.5 and 5 years, indicating a special status for fearful faces on attention during early childhood. In regard to attention to happy faces, previous studies using the overlap paradigm suggest that the attention bias for happy versus neutral faces emerges by 2 years of age (Kataja et al., 2020; Leppänen et al., 2018; Peltola et al., 2009, 2008, 2018). According to the findings of the present study, the bias in attention orienting and sustained attention for happy versus neutral faces is prevalent among children still at 2.5 and 5 years of age. However, it cannot be ruled out that infants younger than 2 years demonstrate an attention bias for happy versus neutral faces when they are presented simultaneously, because in the overlap task, the attentional competition is between a facial expression and neutral distractor stimulus. This is an important topic for future studies to address.

Also, as expected, the attention bias for fearful faces was seen both in 2.5- and 5-year-old children in attention orienting and sustained attention and the biases increased with age. These results are in line with the previous studies using the overlap paradigm showing an attention bias for fearful versus neutral faces in attentional disengagement in 2- and 3-year-old children (Nakagawa & Sukigara, 2012; Peltola et al., 2018). In conclusion, it seems that the attention bias for fearful versus neutral and happy faces emerges between 5 and 7 months of age and is still the strongest emotional attention bias at 2.5 and 5 years of age.

We found a bias in sustained attention for the angry versus neutral faces at 2.5 and 5 years of age and this bias increased between 2.5 and 5 years. This is in contrast with the previous study by Dodd et al. (2020), which did not demonstrate a bias in sustained attention for angry faces among 3- and 4-year-olds. We found no evidence for an attention-orienting bias for angry versus neutral faces, which is in line with a previous study by Pérez-Edgar at al. (2011) but in contrast to the study by Burris et al. (2017), both using the dot-probe task. It has been hypothesized, mainly based on the attention-bias modification training studies, that a greater attention bias for threat may have causal effects on the increase in anxiety symptom levels and a smaller attention bias for threat, for instance, after the attention bias modification training intervention has been associated with a decrease in anxiety symptom levels (Hakamata et al., 2010; Van Bockstaele et al., 2014). According to our results, the bias in sustained attention for angry faces, which is an attention bias for threat, increases between 2.5 and 5 years in typical development, which needs to considered when the relation between threat bias and social-emotional functioning is studied during early childhood.

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 at the individual level. Yet, they are reliable measures of affect-biased attention at a group level (Cousijn at 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). In the present study, the main aim was to describe the affect-biased attention and its developmental change during early childhood at group level using experimental design. Therefore, poor internal consistency does not compromise these results. However, the poor internal consistency compromises the reliability of the correlational analyses between 2.5 and 5 years and the results should be interpreted with caution. There are some possible solutions to the reliability problem. A higher number of trials per condition could solve the problem. In the present study, the reliability estimates across all 36 trials are at acceptable levels while the reliability measures calculated separately for all conditions with only 6 trials show poor or unacceptable internal consistency. However, higher number of trials has not solved the problem of poor internal consistency in previous studies among children (Dodd et al., 2020). Also, as seen in our data, the child’s responses to stimuli change over the course of time not just as decreased interest but in a complex way, which indicates that the gaze behavior in one trial may be affected by the previous trials. It has been argued, that combining information from multiple measures of affect-biased attention at multiple levels of analyses increases the reliability at individual level (Rodenbauch et al., 2016; Vallorani et al., 2021). In conclusion, when using free-viewing of paired emotional face pictures with children, reliability remains a concern and large sample sizes may be needed.

Our findings indicate that there are age-typical changes in attention biases. More specifically, the main changes in affect-biased attention between 2.5 and 5 years were the emergence of an attention-orienting bias for sad faces and an increase in biases in sustained attention for happy, fearful, angry and sad facial expressions. These results are in contradiction to the integral bias model that assumes no changes in attention biases during the development and also in contradiction to the moderation model that assumes diminishing attention biases over the course of the development (Field & Lester, 2010). Instead, our results are in line with the acquisition model that assumes that the attention biases may emerge during the development linked with cognitive, emotional and social development (Field & Lester, 2010; Leppänen & Nelson, 2012). Based on previous studies, for example, during infancy, an attention bias for faces, and, specifically, for happy faces during the first 6 months after birth, may support bonding between the infant and the caregivers (Farroni et al., 2007; Ramsey & Langlois, 2002; Symons et al., 1998). During the second half of the first year, fear processing undergoes rapid development, while motor functions become more independent and the need for the ability to discriminate between familiar attachment figures from other people increases (Bertenthal & Campos, 1984; Bowlby, 1969; Leppänen & Nelson, 2012; Symons et al., 1998). It can be speculated that our findings of increased biases in sustained attention for emotional facial expressions between 2.5 and 5 years may reflect more independent behaviors and more complex social interactions at 5 years compared to 2.5 years. For example, between 1 and 2 years of age, toddlers start to demonstrate a differential use of goal-directed behaviors in response to discrete emotions, such as a more relaxed play in response to an adult's joy or social avoidance and security seeking in response to an adult's anger (Walle et al., 2017). Finally, our results are in line with the hybrid model briefly described by Field and Lester (2010) and expanded by Morales et al. (2016) proposing that there are innate attention biases that are based on individual factors and that are moderated by factors intrinsic and extrinsic to the child later during development. The key question separating the acquisition model and the hybrid model is whether attention biases are innate or emerge during development. As our first measurement point is at 2.5 years, our data do not provide new information about the emergence of attention biases.

Our findings show low correlations between the biases in sustained attention at 2.5 and 5 years, which may reflect developmental changes caused by, for example, typical neural maturation or environmental factors. The model by Morales et al. (2016) explains this low stability by proposing that affect-biased attention has reciprocal connections to a child's socioemotional functioning and may be malleable for social-emotional factors both intrinsic, such as temperament, and extrinsic to the child, such as received caregiving behaviors. Interestingly, we found a moderate correlation between latencies of the first fixations across all trials, which may indicate some individual stability in saccadic latencies. However, the low correlations can be also explained by poor reliability of attention-orienting bias and the bias in sustained attention. Problems in reliability in eye-tracking data of young children is also reported previously. Attention-orienting bias showed poor split-half reliability in free-viewing of paired emotional face pairs in a study by Dodd et al. (2020). In addition, low test-retest reliability has been observed for young children in eye-tracking experiments and especially for saccadic latencies (Cousijn et al., 2017; Hessels et al., 2016).

One of the limitations of this study concerns the facial stimuli. The teeth of the actress were seen only in the happy and fearful pictures. According to previous studies, teeth attract attention orienting (Blanco et al., 2017; Calvo & Nummenmaa, 2008). However, the fixation heatmaps on faces suggest that the mouth captures children's attention even if the teeth were not visible. In addition, some of our results could not be fully explained by the presence of teeth alone, as, for example, we found a higher bias in sustained attention for fearful faces compared to happy faces, for which teeth are both visible in the pictures. Another limitation is that during the task, the same neutral face stimulus was paired with all other stimuli. It is possible that the children habituated to it, and, thus, showed increased attention to other facial expressions. However, the correlation between the trial number and total fixation time for neutral faces was low indicating low habituation for the neutral face over the course of the task. In addition, children showed a clear attention-orienting bias for the neutral face versus the non-face picture at both 2.5 and 5 years rendering this explanation less likely. Also, we observed differences between facial expressions, for example, bias in sustained attention for fearful versus neutral faces was higher than for happy, sad or angry faces versus neutral faces. These findings were not affected by this potential confounding factor.

The findings of this study can be most likely generalized among children with European origin. However, it is possible that similar patterns in affect-biased attention can be found among children from other cultures, as has been demonstrated among infants (Pyykkö et al., 2019). Also, there might be other sources of systematic variance in the background variables in our sample, such as relatively high levels of parental education, that may affect the generalizability of our results. We see these generalizability issues as an important topic for research in the future. In addition, the findings of emotional attention biases apply only for face pairs in which a neutral face is contrasted to an emotional face. Other face pairs, such as pairs of a positive and a negative face in a study by Lagattuta & Kramer (2017), have demonstrated different phenomena, such as a general attention bias for negative faces over positive facial expressions.

Conclusions

Our results indicate that children show attention biases in sustained attention for happy, fearful, sad and angry faces at 2.5 and 5 years of age. The attention biases were detected using eye tracking during the free viewing of paired pictures. All biases in sustained attention increased between 2.5 and 5 years of age. This study is the first to demonstrate these effects in a large follow-up sample of typically developing children. The emotional attention biases are changing during this age range that encompass important stages of brain development and acquisition of social and cognitive skills and emotion regulation, which makes them interesting features for future studies in developmental cognitive neuroscience.

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Tables

Table 1. Demographic information of the participants at the 2.5- and 5-year follow-up visits.

	2.5 years *n* = 367 *n* (%) or *mean* (*SD*)	5 years *n* = 477 *n* (%) or *mean* (*SD*)
Child sex (girls/boys), missing *n* = 4	168 (45.8%) /195 (53.1%)	266 (55.8%) / 211 (44.2%)
Child gestational age at birth, weeks	39.88 (1.45) missing *n* = 4	39.70 (1.74)
Maternal age at the delivery, years	31.03 (4.42) missing *n* = 4	31.17 (4.48) missing *n* = 10
Maternal education		
High school, vocational school or lower	87 (23.7%)	113 (23.7%)
Tertiary vocational	113 (30.8%)	132 (27.7%)
University	151 (41.1%)	217 (45.5%)
missing	11 (3.0%)	15 (3.1%)
Paternal age at the child's delivery, years	32.45 (4.99) missing *n* = 103	32.49 (5.26) missing *n* = 126
Paternal education,		
High school, vocational school or lower	91 (24.8%)	104 (21.8%)
Tertiary vocational	74 (20.2%)	103 (21.6%)
University	70 (19.1%)	106 (22.2%)
Missing	132 (36.0%)	163 (34.1%)

Table 2. Descriptive statistics for the number of valid trials and fixation time for non-neutral and neutral face per face condition: mean, standard deviation, median, minimum and maximum.

	Face condition		Number of valid trials			Fixation time (ms)			
						non-neutral		neutral	
		n	*mean* (*sd*)	*md*	*min.*, *max.*	*mean* *(sd)*	*min.*, *max.*	*mean* *(sd)*	*min.*, *max.*
2.5 years	control	365	4.90 (1.35)	5	1, 6	10037.87 (672.59)	0, 3596	1680.02 (783.35)	0, 3632
	happy	363	4.93 (1.30)	5	1, 6	1567.46 (848.44)	0, 3660	1120.62 (735.47)	0, 3648
	sad	363	4.86 (1.37)	5	1, 6	1464.52 (883.72)	0, 3656	1172.00 (776.23)	0, 3636
	angry	360	4.85 (1.33)	5	1, 6	1483.75 (886.72)	0, 3658	1178.26 (766.75)	0, 3648
	fearful	362	4.81 (1.35)	5	1, 6	1706.06 (852.88)	0, 3624	1032.83 (674.13)	0, 3566
5 years	control	464	1.90 (0.30)	2	1, 2	1464.19 (682.29)	0, 3202	1425.85 (673.56)	0, 3582
	happy	473	5.48 (0.88)	6	1, 6	1723.34 (742.95)	0, 3626	1132.22 (651.03)	0, 3608
	sad	472	5.55 (0.83)	6	1, 6	1704.16 (755.45)	0, 3622	1129.32 (658.19)	0, 3670
	angry	474	5.49 (0.89)	6	1, 6	1761.13 (777.80)	0, 3658	1115.32 (667.19)	0, 3692
	fearful	472	5.53 (0.86)	6	1, 6	1923.36 (748.66)	0, 3686	960.16 (610.60)	0, 3656

Table 3. The estimated mean latency to first fixation, probabilities of first fixation, i.e., attention-orienting bias and bias in sustained attention for a happy, sad, angry or fearful face or a non-face picture with 95% confidence intervals.

Age	Face	Estimate	*CI* 95%	*p*
Mean latency to first fixation in non-neutral face (ms)				
2.5 years				
	Non-face	427	[418, 437]	
	Happy	400	[391, 408]	
	Sad	407	[399, 416]	
	Angry	405	[397, 414]	
	Fearful	413	[405, 421]	
5 years				
	Non-face	441	[428, 455]	
	Happy	379	[373, 386]	
	Sad	384	[378, 391]	
	Angry	390	[383, 397]	
	Fearful	384	[378, 391]	
Attention-orienting bias				
2.5 years				
	Non-face	0.372	[0.350, 0.395]	<.001
	Happy	0.554	[0.530, 0.577]	<.001
	Sad	0.495	[0.471, 0.518]	.648
	Angry	0.482	[0.459, 0.506]	.147
	Fearful	0.533	[0.509, 0.556]	.007
5 years				
	Non-face	0.269	[0.241, 0.300]	<.001
	Happy	0.628	[0.608, 0.646]	<.001
	Sad	0.549	[0.529, 0.569]	<.001
	Angry	0.506	[0.487, 0.526]	.531
	Fearful	0.607	[0.588, 0.626]	<.001
Bias in sustained attention				
2.5 years				
	Non-face	-0.24	[-0.26, -0.21]	<.001
	Happy	0.15	[0.13, 0.18]	<.001
	Sad	0.08	[0.06, 0.10]	<.001
	Angry	0.09	[0.07, 0.12]	<.001
	Fearful	0.21	[0.19, 0.24]	<.001
5 years				
	Non-face	0.01	[-0.02, 0.04]	.633
	Happy	0.21	[0.19, 0.23]	<.001
	Sad	0.19	[0.18, 0.21]	<.001
	Angry	0.21	[0.19, 0.23]	<.001
	Fearful	0.33	[0.31, 0.35]	<.001

Table 4. Reliability estimates separately for each face condition and across all conditions: split-half reliability and Cronbach's alpha.

	Face	Split-half Reliability	Cronbach's Alpha [*CI* 95%]
Latency to 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]

Table 5. Differences in latencies to first fixation on 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 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

Table 6. 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

Table 7. Pearson correlations for latencies to first fixation on the non-neutral faces between different facial expressions and different age groups (at 2.5 and 5 years old). 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.

	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***

Table 8. Pearson correlations for probabilities of first fixation to a non-neutral face, i.e., attention-orienting bias between different facial expressions and different age points (2.5 and 5 years). 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.

	2.5 years				**5 years**			
	Non-face	**Happy**	**Sad**	**Angry**	**Fearful**	**Non-face**	**Happy**	**Sad**	**Angry**
2.5 years									
Happy	-.10								
Sad	-.001	.17**							
Angry	.16**	-.25***	-.22***						
Fearful	-.08	.31***	.29***	-.13*					
5 years									
Non-face	.13	.07	-.01	.07	.08				
Happy	.04	.03	.05	.01	-.01	-.04			
Sad	-.01	-.03	.02	.01	.02	-.03	.11*		
Angry	.06	.09	.07	.01	.14*	.03	0	.06	
Fearful	-.04	0	.05	-.06	.09	.12*	.26***	.15**	.02

Table 9. Pearson correlations for bias in sustained attention for different emotions between different facial expressions and different age groups (2.5 and 5 years). 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 darker gray background.

	2.5 years					**5 years**			
	Non-face	**Happy**	**Sad**	**Angry**	**Fearful**	**Non-face**	**Happy**	**Sad**	**Angry**
2.5 years									
Happy	.06								
Sad	.03	.04							
Angry	.02	.07	-.01						
Fearful	.03	.13*	.17**	.11*					
5 years									
Non-face	.19**	.09	.06	-.01	-.1				
Happy	.04	-.05	.02	-.04	.09	-.03			
Sad	.11	-.02	0	-.03	.03	.05	-.03		
Angry	.06	.1	.09	.21**	.19**	.1*	.04	.12**	
Fearful	.07	-.02	-.06	.02	.02	.02	.09*	.10*	.16***

Figures

Figure 1. The flow chart of the recruitment process and data loss.

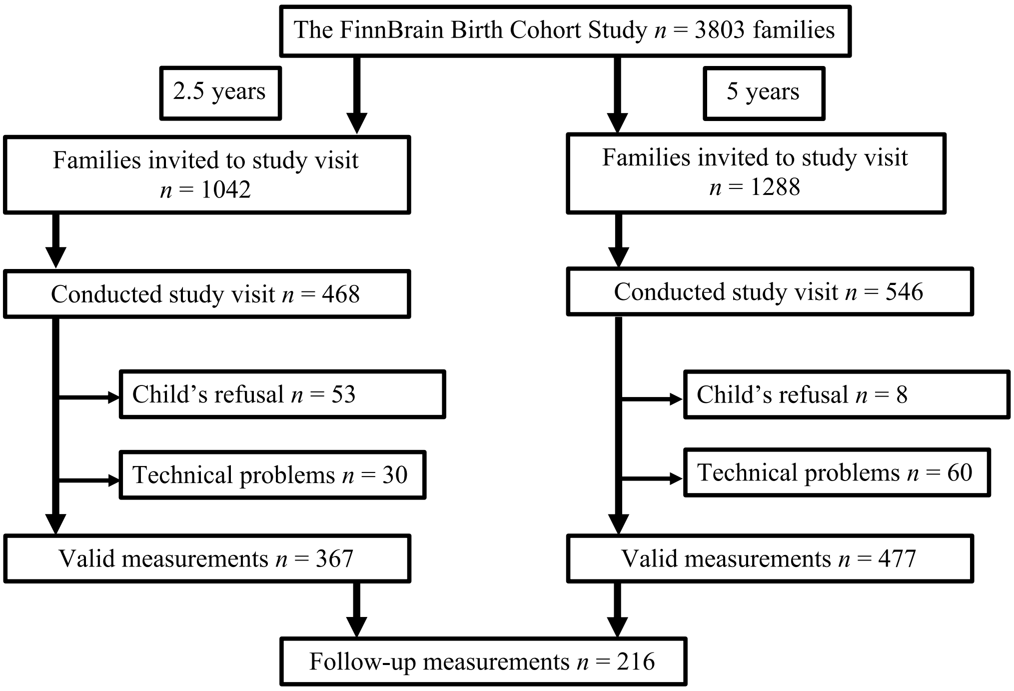

Figure 2. Stimuli of the emotional face pair task.

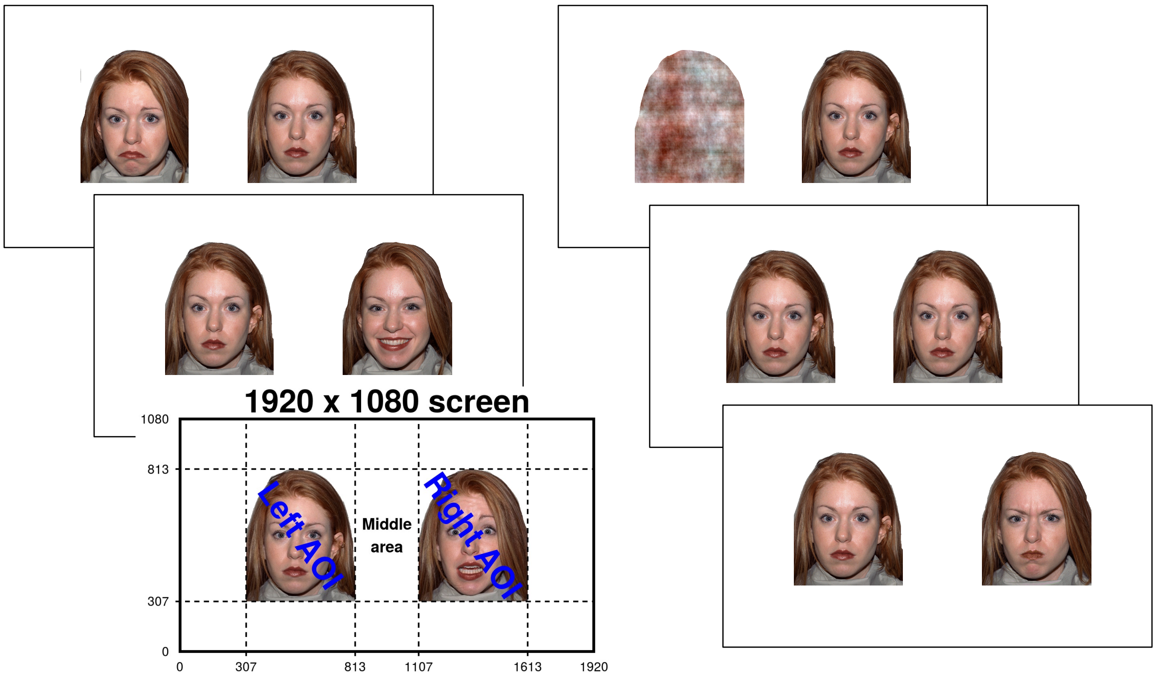

Figure 3. Timeline for attention to emotional faces during the free viewing of face pairs, i.e., for each face and for each 50 ms time interval, as the percentage of all trials in the study where the children fixated at that face. The dashed grey lines are at 150 ms and 4000 ms, i.e., the limits of the time interval from which the data were included in the study.

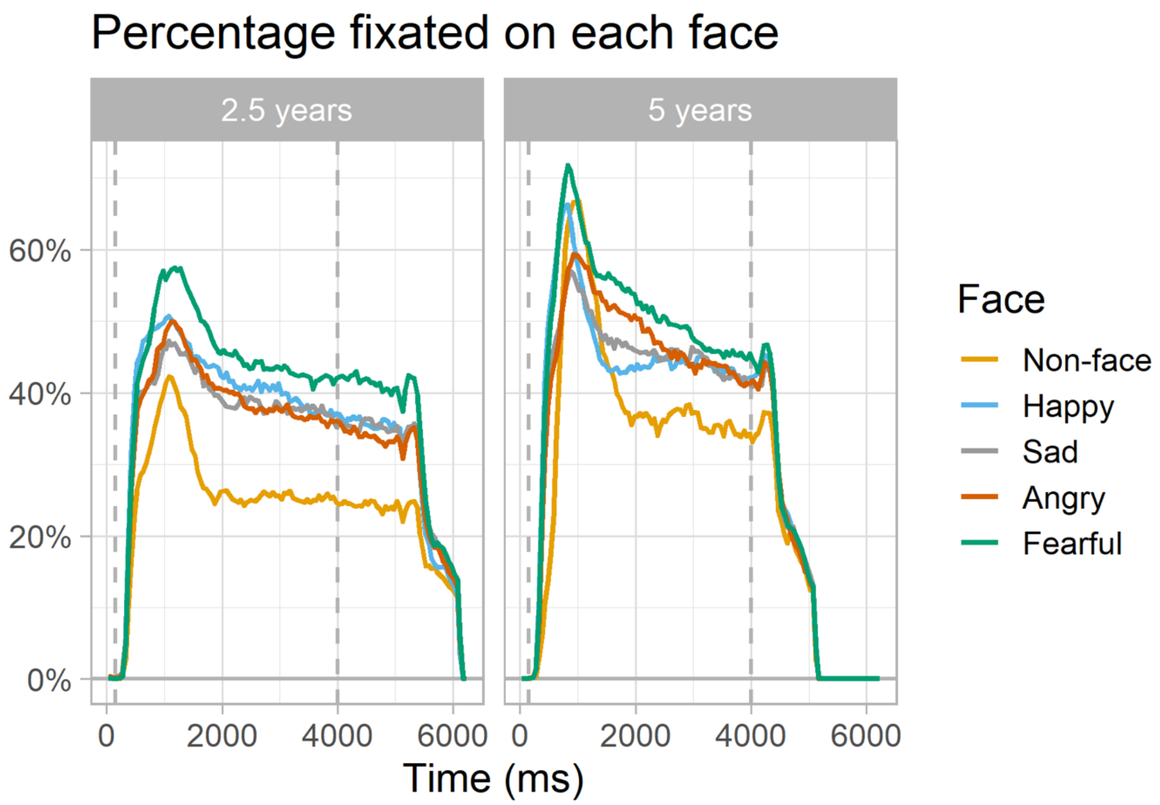

Figure 4. Spatial distributions of gaze across all face pairs at 2.5 and 5 years of age. The color indicates the proportion of fixations at each 30 x 30 pixel area with the darker green color indicating that the participants fixated more frequently on that area and no added color means no fixations on 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.

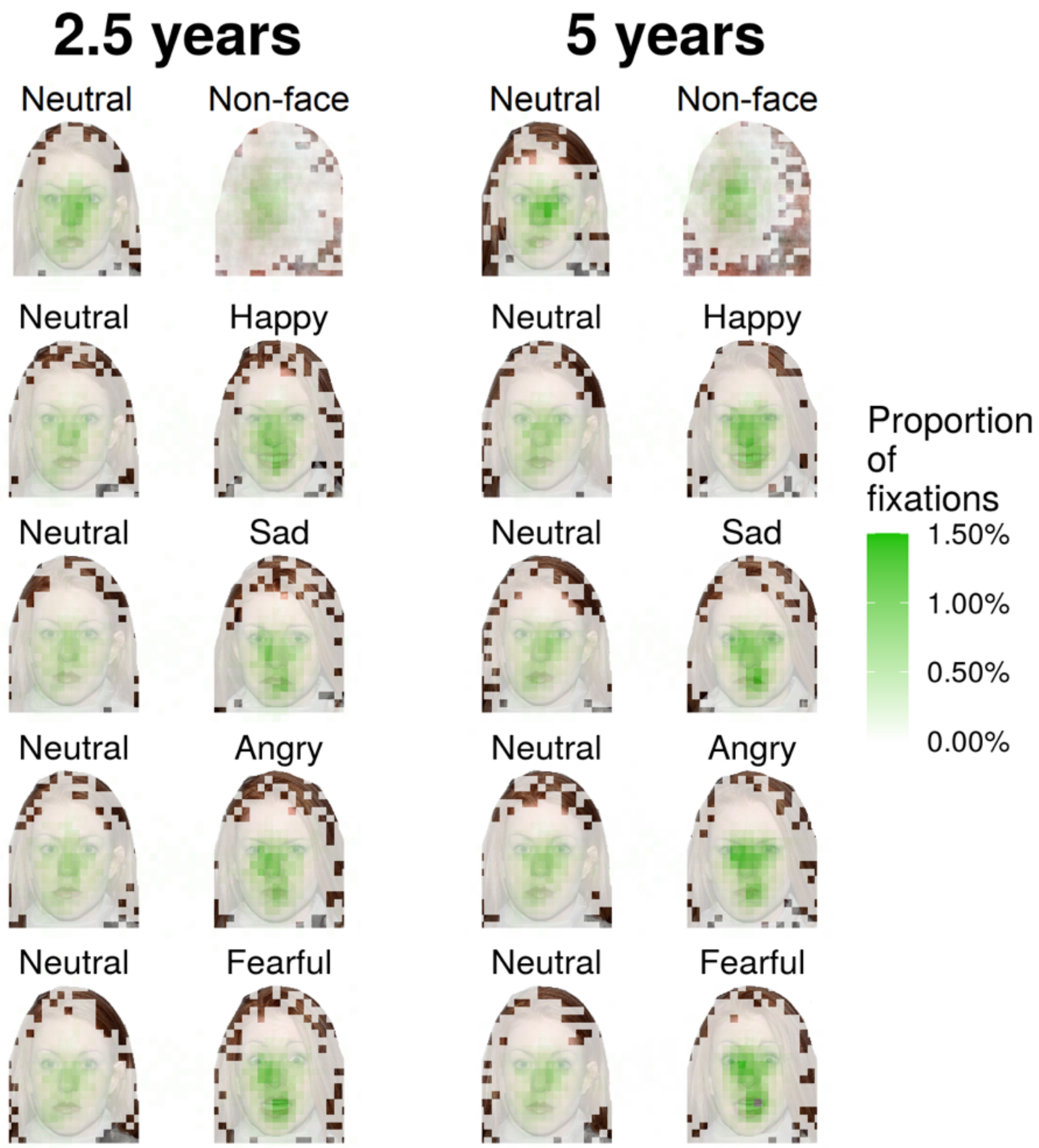

Figure 5. Estimated mean latencies to first fixation on non-face pictures from Model 1, and happy, sad, angry and fearful faces for the trials where the first fixation was in a non-neutral face. The error bars denote 95% CIs.

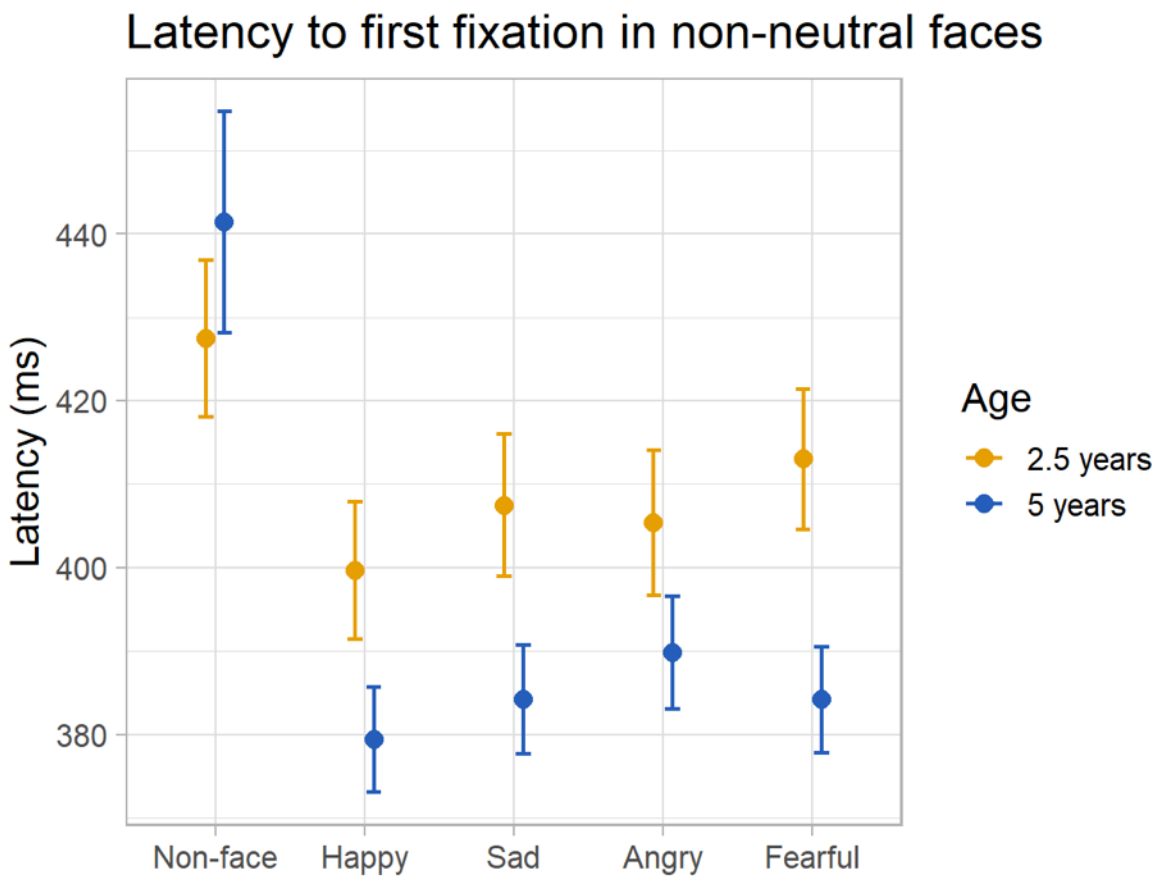

Figure 6. Probability to fixate first the non-face picture, happy, sad, angry or fearful face at 2.5 and 5 years of age. The error bars denote 95% CIs. The values above the dashed grey line represent an attention-orienting bias towards the stimulus.

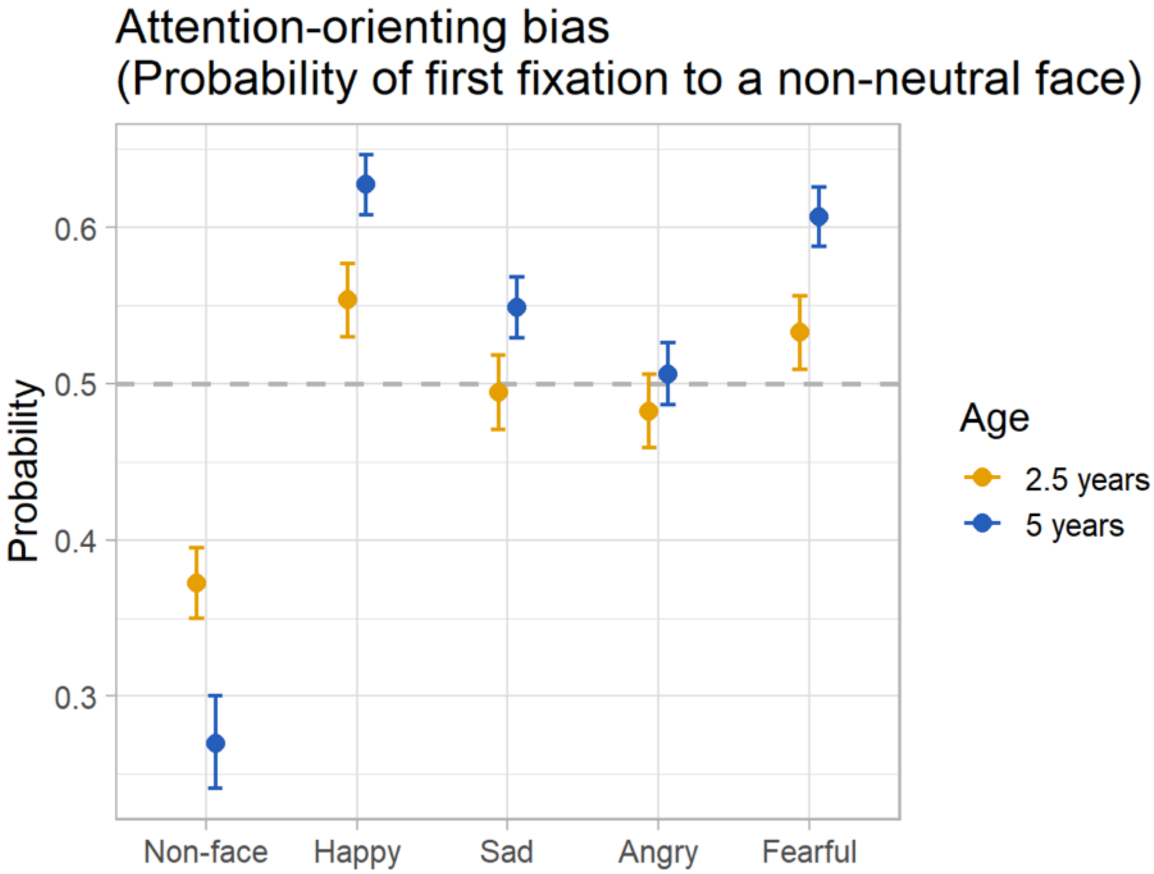

Figure 7. Estimated mean bias in sustained attention from Model 3 for happy, sad, angry and fearful faces and for the non-face picture. The error bars denote 95% CIs.