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The stability of early-developing attentional bias for faces and fear from 8 to 30 and 60 months in the FinnBrain Birth Cohort study

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ABSTRACT

Most infants exhibit an attentional bias for faces and fearful facial expressions. These biases reduce towards the third year of life, but little is known about the development of the biases beyond early childhood. We used the same methodology longitudinally to assess attention disengagement patterns from non-face control pictures and faces (neutral, happy, fearful expressions) in a large sample of children at 8, 30, and 60 months (N=389/393/492, respectively; N=72 for data in all three assessment; girls >45.3% in each assessment). "Face bias" was measured as a difference in disengagement probability (DP) from faces (neutral/happy) vs. non-face patterns. "Fear bias" was calculated as a difference in DP for fearful vs. happy/neutral faces. At group level, DPs followed a non-linear longitudinal trajectory in all face conditions, being lowest at 8 months, highest at 30 months, and intermediate at 60 months. Face bias declined between 8 and 30 months, but did not change between 30 and 60 months. Fear bias declined linearly from 8 to 60 months. Individual differences in disengagement were generally not stable across age, but weak correlations were found in face bias between 8- and 60-month, and in DPs between 30- and 60-month (*r*s .22–.41). The results suggest that prioritized attention to faces – i.e., a hallmark of infant cognition and a key aspect of human social behavior – follows a non-linear trajectory in early childhood and may have only weak continuity from infancy to mid childhood.

Key words; attention bias; face bias; fear bias; eye tracking;

INTRODUCTION

Infants exhibit an early-developing preference, i.e., attention bias, towards faces (or face-like stimuli) over other visual objects (Reynolds & Roth, 2018). This “face bias” may be tractable even through the uterine wall (Reid et al., 2017; Reissland et al., 2020; but see Scheel et al., 2018). At birth, the bias manifests as preferential turning of the head and gaze towards geometric patterns that resemble human faces as compared to non-face patterns (Johnson, 2005). Between 3 and 9 months, infants become increasingly more likely to direct their first look towards faces than to other salient objects when viewing an image depicting a naturalistic scene (Kelly et al., 2019), fixate faces longer than other simultaneous present static or dynamic stimuli (Gluckman & Johnson, 2013), and are less likely to disengage from faces than patterns, particularly when the faces display a fearful as compared to happy, angry, or neutral expression (Kataja et al., 2018; Leppänen et al., 2018; Peltola et al., 2008; Pyykkö et al., 2019). Infants may be particularly attentive to fearful faces because of the novelty of this expression, some specific features of this expression (e.g., eyes wide open or an enlarged white scleral field around the pupil), or because of the affective and/or social signal value of this expression (e.g., Johnson, 2005; Leppänen, Cataldo, Bosquet Enlow, & Nelson, 2018).

While faces attract more attention than patterns, the strength of this bias can vary considerably between individuals. For example, the mean probability of gaze disengagement from a picture of face upon presentation of a competing lateral stimulus varies from 0 to 1 in 6- to 9-month-old infants (Pyykkö et al., 2019). These variations are moderately stable between 5 and 7 as well as between 9 and 11 months of age (Leppänen et al., 2015), and have been found to be correlated with prosocial behaviors in early childhood (Peltola et al., 2018; see also Bedford et al., 2014).

The early-emerging variations in disengagement from faces may represent a precursor for individual differences in tendency to fixate faces in complex, naturalistic scenes in adults and associated variations in social cognition (De Haas et al., 2019; Guy et al., 2019). However, only a few studies have actually tested whether the variations in look durations for faces persist beyond the first year of life. The results of these studies suggest that the bias for faces (i.e., reduced gaze disengagement from faces) attenuates noticeably after the first year of life at 2 or 3 years of age and that the individual variations that are found in infancy are not stable between 7 and 24 months (Peltola et al., 2018) or 5-12 and 36 months (Xie et al., 2021; see also Nakagawa & Sukigara, 2012 and Nishizato et al., 2017), regardless of whether the faces displayed happy/neutral or fearful emotion. The low stability of the reduced disengagement from faces vs. non-face patterns beyond infancy raises the possibility that this bias may be a transient developmental phenomenon that declines by age and is developmentally distinct from the biases in looking behavior found at older ages. This conclusion may be premature, however, as no longitudinal studies have yet used the same methodology to examine the stability of this bias beyond early childhood (i.e., beyond the age of 24 or 36 months).

In the current study, we used a spatial overlap task (Peltola et al., 2009) to examine attention disengagement from neutral, happy, and fearful faces as well non-face patterns towards lateral distractors at 8, 30, and 60 months of age. The overlap task measures attention disengagement from a stimulus at fixation to an abrupt onset of a new stimulus in the lateral visual field. An attentional bias for faces manifests in this paradigm as reduced likelihood of quick attention disengagement from faces than non-faces, and the bias for fearful faces as reduced likelihood of quick disengagement from fearful vs. neutral/happy expressions (Pyykkö et al., 2019). Our aims in this exploratory study were, first, to examine changes in attention disengagement from faces and non-faces as well as changes in biases towards faces and fearful facial expressions between 8, 30, and 60 months at group level. Second, we examined whether individual differences in attentional disengagement and biases were stable from infancy to mid childhood. We report the results from (partially overlapping) samples of N=389 8-month-olds, N=393 30-month-olds, and N=492 60-month-olds as well as a subsample of children assessed longitudinally at 8 and 30 months (N=159), and at 30 and 60 months (N=180). N=72 children were assessed in all three time points.

METHODS

Participants

The data for the current analyses were obtained from the FinnBrain Birth Cohort Study (Karlsson et al., 2018). The FinnBrain is a large prospective longitudinal study aimed to study the effects of pre- and postnatal stress on the developing brain, self-regulation, and later health (see Karlsson et al., 2018 and Kataja et al., 2018) for details). The cohort comprises 3808 families that have been followed from early pregnancy onwards. Measures completed in the whole cohort population are questionnaires and register linkage, while smaller study populations are invited to the study visits, such as eye movement tracking, for resource allocation reasons. Inside the main cohort, a “Focus Cohort” with a target population of 1217 women (and their children) has been established to especially focus on investigating the development of children exposed to high vs. low levels of prenatal maternal distress (i.e., depressive, general anxiety, and/or pregnancy-related anxiety symptoms; Karlsson et al., 2018). For this study, the Focus Cohort subjects enriched by basic cohort population mothers and their children were invited. The enrichment was made in order to ensure representative distribution of maternal distress exposure in the eye-movement tracking study population. The number of the families that were contacted for this study varies according to the resources available at the cohort but was unrelated to the characteristics of the study subjects. A description of the participant subgroups is provided in Table 1.

Table 1

The number of participants from different subgroups of the longitudinal cohort at the three eye-tracking assessments

Number of participants	Age (months)

	8	30	60
Contacted/invited	694	1042	1288
Participated	488	468	545
Assessed with eye tracking	421	434	545
Maternal prenatal distress (High/other/low)	134/49/207	105/100/188	112/188/192
N in analyses with mixed models	390	393	492

During the visits, the mothers gave written informed consent on behalf of their children. They were also 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 (*FinnBrain Study – Investigating emotion system development with infant eye-movement tracking*; 20.11.2012; ETMK:107/180/2012 §322). The study was conducted in full compliance with the Helsinki Declaration.

Data availability statement: Requests for collaboration, including access to the data, are considered by the Steering Committee of the FinnBrain Birth Cohort Study. International and domestic collaboration is encouraged and inherent in the project, and the ultimate goal is that the data will be available as easily as possible for the research community. The study was not preregistered.

Attrition analyses

The children who participated in 8-month but not in 30-month visits did not differ in terms of maternal parity (primi- vs. multipara; chi square p = .758), gestational weeks at child birth (t test, p = .387), maternal education (high/middle/low; chi square p = .124), or Focus Cohort membership (maternal high/other/low prenatal distress; chi square p = .252). However, they differed in terms of maternal age (t(387)=-2.54, p = .012, 95% CI -1.95–.25); those not participating at the child age of 30 months had younger mothers (M=30.18, SD=4.30) than those participating at the child age of 8 and 30 months (M=31.28, SD=4.23). Further, children who participated in 8-month but not in 60-month visits did not differ in terms of maternal parity (primi- vs. multipara; chi square *p* = .501), gestational weeks at childbirth (t test, *p* = .570), maternal education (high/middle/low; chi square *p* = .076), maternal age (t test, *p* = .129), or Focus Cohort membership (maternal high/other/low prenatal distress; chi square *p* = .129). We conclude that the key characteristics of study participants were largely similar across the measurement points and thus unaffected by the attrition or the inter-subject differences in the total number of visits.

Table 2

Demographic characteristics of study participants

Variable	Age (months)		
	8	30	60
Boys, N (%)	197 (54.3%)	176 (52.5%)	239 (54.6%)
Girls, N (%)	166 (45.7%)	160 (47.5%)	199 (45.4%)
GA[a] (weeks), M (range)	39.9 (34.4-42.3)	39.93 (31.9-42.3)	39.75 (30.1-42.4)
Mother age at delivery, M (SD)	30.8 (4.3)	31.30 (4.4)	31.13 (4.5)
Maternal education, %			
High school/vocational	28.1%	21.7%	23.5%
Polytechnics	36.2%	29.5%	27.2%
University	33.5%	39.0%	45.7%
Missing information	2.8%	9.8%	3.7%

[a] Gestational age

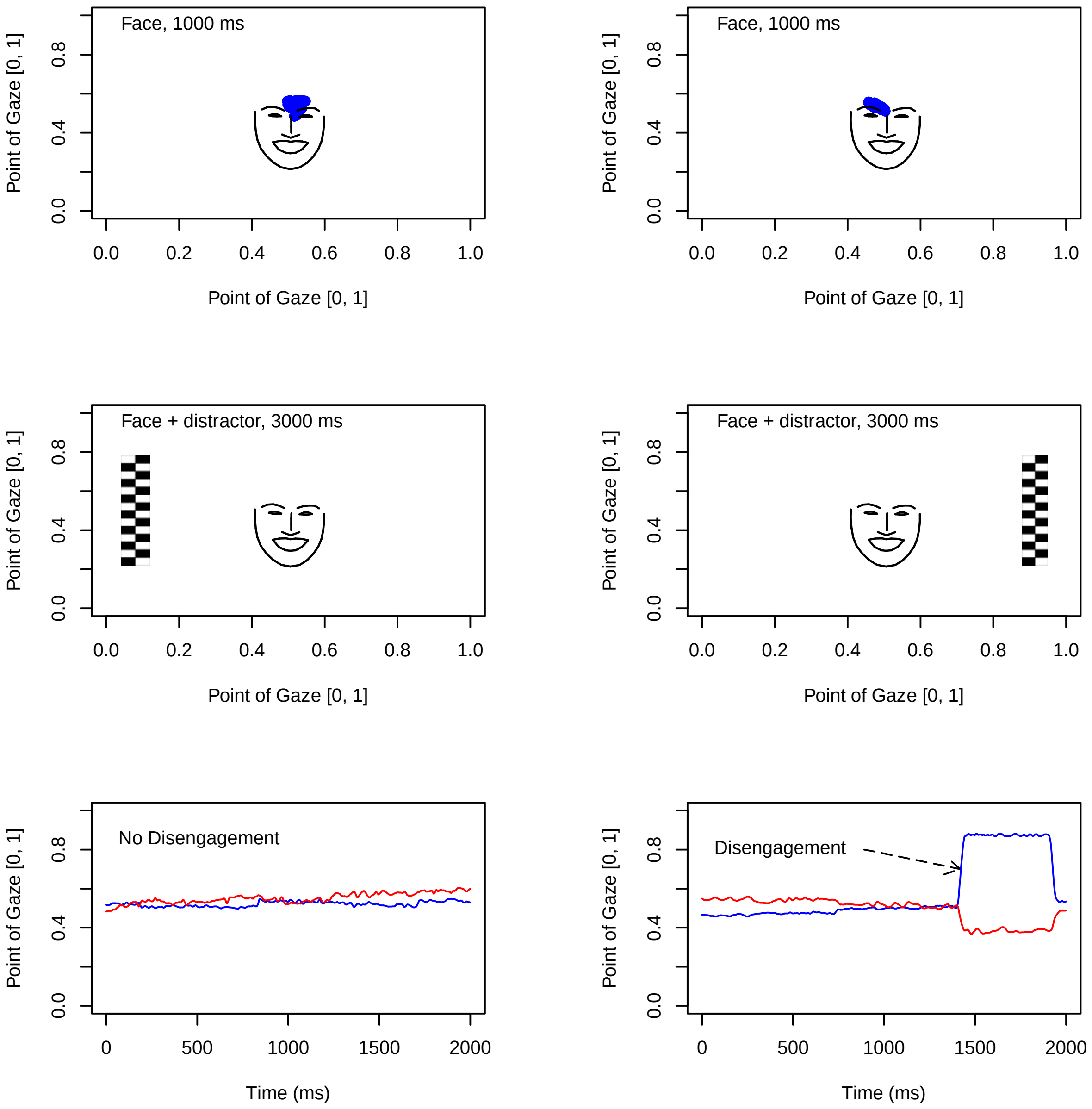
Eye tracking assessments at 8, 30, and 60 months

Eye tracking assessments were conducted in a dimly lit room with a 19” CRT monitor and EyeLink1000+ eye tracker (SR Research Ltd, Toronto, Ontario, Canada). A sampling frequency of 500Hz was used. 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 computer screen and the eye tracker. The researcher sat on a separate host computer next to participant but was separated by a curtain to avoid interference. Before measurement, a five-point calibration procedure, with an audiovisual animation sequentially presented in five locations on the screen, was used. The calibration was repeated before actual testing and also during measurement if the tracker failed to detect the eye (e.g., due to excessive movement or fussing during the experiment). Short breaks were allowed during measurement if needed.

The overlap paradigm (Peltola et al., 2008) was used to assess the child’s attention disengagement from faces and non-faces to distractors (Figure 1). In this paradigm, 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 added on either the left or right side of the screen (at visual angle of 13.6°) for 3000ms. One trial lasted for 4000ms. The sizes of the central face/non-face stimulus and the lateral distractor stimuli were 15.4° x 10.8° and 15.4° x 4.3°, respectively. A brief animation was shown before each trial to capture the attention of the child to the center of the screen. Once the child’s gaze was in the middle of the screen, the trial was initiated manually by the researcher who monitored the child’s gaze from the host computer. The order of the central stimuli was semi-randomized, with a constraint that the same stimulus was not presented more than three times in a row. The lateral stimulus was selected and presented randomly for each trial.

Figure 1

Illustration of the overlap paradigm and data from two example trials



Note. Participants were presented with a face or a non-face in the center of the screen. One second later, a "distractor" was added to the left or to the right. Left: An example of a "no disengagement" trial in which the gaze does not shift from the central to the lateral stimulus. Right: An example of a "disengagement" trial in which the gaze shifts rapidly from the central to the lateral stimulus. The X- and Y-coordinates of the point of gaze on the display are shown by the blue and red lines, respectively. The outline and key landmarks of the face stimulus are shown based on values extracted by the OpenFace 2.2.0 toolkit (Baltrusaitis et al., 2018).

The same overlap paradigm was used at T1–T3, and it was always conducted as the first eye-tracking task. However, the total number of trials and the type of the lateral distractor differed between the visits. At T1, photographs of two female faces with neutral, happy, and fearful expressions as well as non-face control stimuli created by randomizing the phase component of the (fearful) faces of the two models were used. The non-face control stimuli retained the low-level physical properties of the original face images (i.e., colour and amplitude spectra), but were not identifiable as a face after the phase information of the images had been randomized. Altogether, 48 trials were presented, 12 trials per condition (each emotion and the control picture). At T2 and T3, only photographs of one female model posing neutral, happy, and fearful faces and a non-face control stimulus were used, thus including 6 trials per condition, altogether 24 trials. This change was made to reduce the length of the assessment at T2 and T3 as the children were also participating in other eye-tracking experiments during the same visit (these will be reported elsewhere). In our analyses, we use data for the first 24 trials for T1 to increase comparability between the T1–T3 data sets leaving N=1 infant out from the sample (i.e., resulting in N=389 for T1). At T1, the lateral distractor was a static geometric shape (a black and white checkerboard pattern or vertically arranged empty and filled circles). At T2 and T3, the same distractors were used, but at T2 the contrast polarity of the stimulus was reversed at the frequency of 10Hz to increase the saliency of the distractor and at T3 the distractor started to flash after the child directed attention towards it (see Leppänen, Cataldo, Enlow, et al., 2018; Peltola et al., 2018 for similar adjustments).

Preprocessing of eye-tracking data

The trial data, comprising of timestamps for the onset times of central and lateral pictures and the xy coordinates of the participants' gaze position (500 samples per second) were stored as text files, and analyzed using a library of MATLAB functions (MathWorks, Natick, MA) (Leppänen et al., 2015). The following criteria were used to ensure the quality of the trials retained in the analysis. These parameters were set a priori based on prior studies using the same methodology and analytic approach (Kataja et al., 2020; Leppänen et al., 2015). First, trials had to have sufficient looking at the central stimulus (>70%) during a time interval that started at the onset of the trial, i.e., appearance of the face or non-face on the screen, 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 a sufficient number of valid samples in the gaze data with no gaps greater than 200 ms. This meant that gaps in the data were extrapolated by the analysis script by carrying the last recorded sample forward, but if the gap was greater than 200 ms, the trial was flagged as invalid and excluded from subsequent analyses. Thirdly, if disengagement occurred during the trial, the exact timing of the eye movement from the central to the lateral stimulus was required to be known for the trial to be included in the analysis, i.e., if the eye movement occurred during a period of missing or extrapolated gaze data, the trial was rejected. Mean percentage of valid data by stimulus condition and age as well as the percentage of data excluded based on different exclusion criteria are provided in Supplementary Table 1 and Supplementary Figure 1.

Eye tracking measures

In prior studies using the current methodology to assess infants' attentional disengagement, trial-level eye-tracking data have been analyzed by coding the data into a binary disengagement value (0/1) based on whether or not the gaze shifted from the central to the lateral stimulus (i.e., disengagement probability, DPs) or by extracting the latency of the gaze shift. The trial-level data have been aggregated to estimate mean disengagement probability (DP) or mean disengagement time (DT). The latter has also been variably calculated excluding or including censored values (i.e., trials on which no disengagement was observed by the end of the trial period; Pyykkö et al., 2019). DPs and DTs are typically highly positively correlated, and the correlations were high in the current study as well (*r*s

> .89). In the current study, we used binary disengagement variables and mean DPs as our primary measures of disengagement.

Statistical Methods

Primary analyses of eye-tracking data were conducted to examine age-related changes in DPs using a mixed effects logistic regression (MELR) model with the binary disengagement variable (disengagement or no disengagement on each trial) as the response variable. The fixed effect structure of the model was:

Intercept + *Condition* + *AgePoint* + *Condition x AgePoint* + *TrialNumber*

and the random effects were

Intercept + *Condition* + *AgePoint* + *Condition x AgePoint*

for each child. Here, *Condition* and *AgePoint* are categorical variables indicating condition (control, neutral, happy or fearful) and age point (8, 30 or 60 months), respectively, and *TrialNumber* is a continuous variable indicating the number of the trial (1-24).

The model thus assumed that at the group level there is a population average DP for each condition at each age point (the fixed effects) and, furthermore, that each child has a personal latent DP for each condition at each age point (the random effects). The DPs were also allowed to depend on the trial number (at the group level) as we observed that they depended on it somewhat strongly (Kataja et al., 2018). Trials were then assumed conditionally independent given the individual latent DPs and trial number.

Face bias was defined here as the ratio of geometric mean odds of disengaging from the control stimulus to the odds of disengaging from happy and neutral conditions (Kataja et al., 2018). That is, if infants show increased attention for the happy and neutral face compared to the control stimulus, then the face bias is OR > 1. Fear bias was defined in a similar way as the face bias but it compared the odds of disengaging from the happy and neutral faces to the odds of disengaging from the fearful faces (Kataja et al., 2018). That is, a fear bias with an OR > 1 indicates that infants show increased attention for the fearful faces compared to the happy and neutral faces. Face bias was defined in a similar way as fear bias but it compared the DP of the control stimulus to the DPs of the happy and neutral conditions (Kataja et al., 2018). That is, if infants show increased attention for the happy and neutral face compared to the control stimulus, then the face bias is OR > 1.

Developmental changes in DPs and bias scores were examined by calculating the Odds Ratios (OR) of change across age. OR > 1 refers to a positive change (i.e., increase) in a measure, and OR < 1 a negative change (i.e., decrease). We also compared the ORs of change between conditions (e.g., face vs. control) and age intervals (8 to 30 months vs. 30 to 60 months) to examine whether the magnitude of change was comparable across conditions or age. The stability of DPs and bias scores was examined by calculating correlations in estimated DPs and bias scores. The estimated correlations between the latent individual DPs are the estimated correlations of the multivariate distribution of the random effects in the logit scale. The correlations between biases were estimated by forming suitable linear combinations of the random effects and using the covariance matrix of the random effects to calculate the correlations between the linear combinations.

The MELR model was fitted by using brm function in the brms package (Bürkner, 2017) in R (R Core Team, 2021) with the default non-informative priors and four Markov chains with 5000 iterations per chain (of which 2000 were warm-up iterations). The intervals presented in the following Results section are thus technically Bayesian credible intervals (CI) but should be practically equal to the corresponding confidence intervals. Results are called statistically significant when zero was not included in the 95% CI and correlation results are marked with *, ** or *** when zero was not included in 95%, 99%, 99.9% CI, respectively.

As the MELR model treats missing data in the response variable automatically, we were able to include all children with at least one valid trial in at least one age point in the main analyses. The sample thus consisted of N = 799 children (389/393/492 children at 8/30/60 months age point. The 8 months data consisted of 48 trials but only the first 24 trials were used in the analysis to make the 8 months results comparable to 30- and 60-month results.

While the main analyses using mixed models made it possible for us to include all children in the analyses (regardless of whether data were available from all three times points), this approach differs from that employed in previous studies. In these studies, the stability of face and fear biases have been examined based on the differences in the mean DPs in different stimulus conditions (e.g., Peltola et al., 2018; Xie, Leppänen, Kane-Grade, & Nelson, 2021; Yrttiaho, Forssman, Kaatiala, & Leppänen, 2014). For comparability, we report similar analyses in the current study. The results of these analyses are provided in the supplementary material and referred to in appropriate places in the results section. Following Yrttiaho et al., (2014), we calculated the "Face bias" as Mean DP control condition – Mean DP neutral and happy face and "Fear bias" as Mean DP neutral and happy face – Mean DP fearful face. Only participants with a minimum of three valid trials in each experimental condition were included in the supplementary analyses based on mean DPs. Group level developmental changes in DPs and bias scores were examined in a sensitivity analysis with a subsample of children with full longitudinal data from 8 to 60 months (N= 72, Supplementary analyses). Stability of individual differences were examined by calculating split-half, odd-even reliability estimates as well as test-retest Pearson correlations for DPs and bias scores between age points (N=127–174).

RESULTS

Developmental changes in disengagement probability, Face bias, and Fear bias

DPs were highest for the control pictures and lowest for the fearful faces in each assessment point (Table 3, Figure 2a), demonstrating an attentional bias for faces and fearful facial expressions at each age. Main analyses concerning age-related changes in DPs and bias scores are shown in Table 4 and Figure 2b.

Comparisons between adjacent age points showed that DPs did not change in the non-face control condition between 8 and 30 months, but there was a significant *increase* in DPs in all face conditions between 8 and 30 months (Table 4). Compared to the change in the control condition, the change in DPs was significantly larger in happy and fearful face conditions. Between 30 and 60 months, there was a significant *decrease* in DPs in all stimulus conditions with no clear differences between control and face conditions. Analyses of bias scores indicated that the bias for faces declined between 8 and 30 months, but there was no decline in the bias between 30 and 60 months (point estimates show a slight increase in the bias between these ages, Table 4). Fear bias score, in turn, declined between 8 and 30 months as well as 30 and 60 months. Thus, there was a quadratic trend for the change in face bias (i.e., the change between 8 and 30 months was significantly larger than the change between 30 and 60 months, OR 2.59 [1.44, 4.50]), and a linear trend in the change score for fear bias (i.e., the change was of similar magnitude from 8 to 30 months and 30 to 60 months).

As a further sensitivity analysis, we examined group-level changes in DPs in a subsample of children with full longitudinal data from 8 to 60 months (N= 72, Supplementary data analyses & Supplementary Table 2). These analyses replicated the main findings by showing a significant Age by Stimulus condition interaction effect on DPs, reflecting less age-related changes in non-face control condition as compared to the face conditions. Age-related changes in face bias were also replicated, whereas there was no difference in fear bias across age in the sensitivity analysis.

Table 3

Disengagement probability and bias scores by age and stimulus condition as estimated by the MELR model

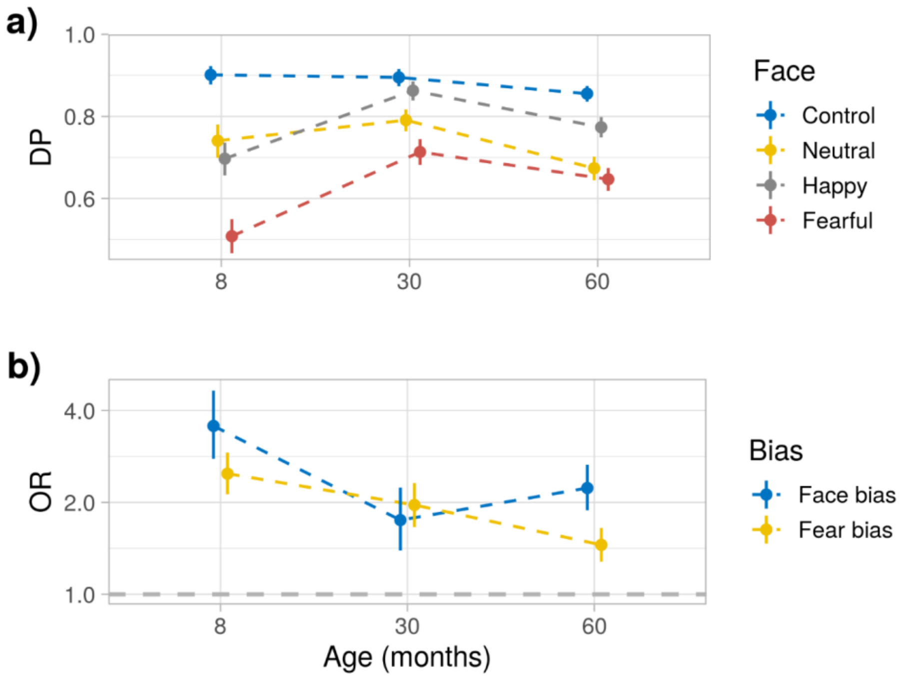
Age (months)	Stimulus/Measure	N	Estimate [95% CI]
	Disengagement probability (DP)[a]		
8	Control	389	0.90 [0.88, 0.92]
30	Control	393	0.90 [0.87, 0.92]
60	Control	492	0.86 [0.84, 0.87]
8	Neutral	389	0.74 [0.70, 0.78]
30	Neutral	393	0.79 [0.76, 0.82]
60	Neutral	492	0.67 [0.64, 0.70]
8	Happy	389	0.70 [0.66, 0.74]
30	Happy	393	0.86 [0.84, 0.89]
60	Happy	492	0.77 [0.75, 0.80]
8	Fearful	389	0.51 [0.47, 0.55]
30	Fearful	393	0.71 [0.68, 0.74]
60	Fearful	492	0.65 [0.62, 0.67]
	Bias scores (OR)[b]		
8	Face bias	389	3.56 [2.78, 4.65]
30	Face bias	393	1.75 [1.39, 2.24]
60	Face bias	492	2.23 [1.88, 2.66]
8	Fear bias	389	2.48 [2.13, 2.91]
30	Fear bias	393	1.96 [1.66, 2.31]
60	Fear bias	492	1.45 [1.28, 1.65]

[a] Estimates of DPs when the effect of trial number was averaged out.

[b] OR>1 indicates a bias towards faces vs. non-faces or fearful vs. happy/neutral faces.

Figure 2

Disengagement probabilities (DPs) for each stimulus condition (a) and for Face and Fear biases (b) at 8, 30, and 60 months (N = 389, 393, 492, respectively), estimated by the MELR model



Note. The error bars indicate the 95% CIs. DPs were estimated while averaging out the effect of trial number.

Stability of individual differences in disengagement probability, face bias, and fear bias

The estimated correlations between the latent individual DPs at 8 and 30 months were generally low and non-consistent (Table 5). Some significant correlations were noted between the 8- and 60-months DPs, and consistent significant correlations between the 30- and 60-months DPs. Some of the estimated correlations between the Face and Fear biases at different age points were close to 0.30, but none of them were statistically significant as the CIs were very wide (Table 6).

The stability of individual differences was also analyzed using bias scores calculated from mean DPs instead of ORs. Spearman-Brown corrected reliability estimates for DPs and bias scores ranged from low to moderate at 8 months for all measures except fear bias (Supplementary Table 3). The estimates were low to moderate for DPs at 30 and 60 months, but the estimates for the bias scores were negligible at the older ages. Face bias at 8 months did not correlate with Face bias at 30 months (p > .59), but correlated positively with the 60-month Face bias (r = .21, p < .05, Supplementary Table 4 & Supplementary Figure 2). No intercorrelations were found in Fear bias between 8, 30 and 60 months (p values > .648, Supplementary Table 4).

Table 4

The Odds Ratios (OR) of change in Disengagement Probabilities (DPs) and bias scores

Variable	Age comparison (months)	OR of change	OR of change vs. Control
Control	8 to 30	0.94 [0.66, 1.31]	
Neutral	8 to 30	1.32 [1.01, 1.74]*	1.41 [0.96, 2.07]
Happy	8 to 30	2.74 [2.09, 3.57]*	2.92 [2.00, 4.29]*
Fearful	8 to 30	2.41 [1.94, 3.02]*	2.57 [1.81, 3.70]*
Control	30 to 60	0.69 [0.52, 0.90]*	
Neutral	30 to 60	0.55 [0.44, 0.67]*	0.79 [0.58, 1.09]
Happy	30 to 60	0.54 [0.43, 0.69]*	0.79 [0.56, 1.09]
Fearful	30 to 60	0.74 [0.61, 0.88]*	1.06 [0.79, 1.44]
Face bias	8 to 30	0.49 [0.35, 0.70]*	
Fear bias	8 to 30	0.79 [0.63, 0.99]*	
Face bias	30 to 60	1.27 [0.94, 1.69]	

Fear bias	30 to 60	0.74 [0.60, 0.91]*
Face bias	8 to 30 vs. 30 to 60	2.59 [1.44, 4.50]*
Fear bias	8 to 30 vs. 30 to 60	0.93 [0.64, 1.38]

Note. OR > 1 refers to a positive change (i.e., increase) in DPs or Bias scores, and OR < 1 indicate negative change (i.e., decrease).
* *p<.05* (2-tailed)

Table 5

Correlations of the estimated Disengagement Probabilities (DPs) across age

Stimulus/age	Stimulus			
	Control	Neutral	Happy	Fearful
		30 months		
Control 8 mo	0.02 [-0.23, 0.28]	-0.17 [-0.41, 0.09]	-0.13 [-0.38, 0.13]	0.10 [-0.15, 0.33]
Neutral 8 mo	0.09 [-0.13, 0.31]	0.01 [-0.21, 0.23]	0.05 [-0.18, 0.27]	0.18 [-0.02, 0.38]
Happy 8 mo	0.15 [-0.08, 0.36]	0.02 [-0.20, 0.24]	0.12 [-0.11, 0.34]	0.22* [0.02, 0.42]
Fearful 8 mo	0.07 [-0.16, 0.31]	-0.03 [-0.26, 0.20]	0.01 [-0.22, 0.25]	0.16 [-0.06, 0.37]
		60 months		
Control 8 mo	0.06 [-0.24, 0.36]	0.29* [0.03, 0.52]	0.21 [-0.05, 0.46]	0.18 [-0.08, 0.44]
Neutral 8 mo	-0.12 [-0.38, 0.16]	0.25* [0.02, 0.47]	0.20 [-0.03, 0.43]	0.14 [-0.09, 0.37]
Happy 8 mo	-0.04 [-0.31, 0.23]	0.32** [0.09, 0.53]	0.24 [-0.01, 0.47]	0.18 [-0.06, 0.41]
Fearful 8 mo	-0.14 [-0.41, 0.15]	0.24 [-0.01, 0.46]	0.18 [-0.08, 0.42]	0.11 [-0.14, 0.34]
		60 months		
Control 30 mo	0.31* [0.03, 0.58]	0.45** [0.22, 0.66]	0.46** [0.22, 0.67]	0.32* [0.07, 0.55]
Neutral 30 mo	0.18 [-0.09, 0.46]	0.31** [0.08, 0.52]	0.26* [0.03, 0.48]	0.26* [0.03, 0.48]
Happy 30 mo	0.25 [-0.04, 0.53]	0.42** [0.18, 0.63]	0.35** [0.10, 0.58]	0.35** [0.10, 0.58]
Fearful 30 mo	0.30* [0.03, 0.55]	0.51** [0.30, 0.69]	0.42** [0.20, 0.62]	0.41** [0.19, 0.62]

* p<.05 (2-tailed); ** p<.01 (2-tailed)

Table 6

Correlations (95% CIs) of the face and fear bias scores across age (8, 30, and 60 months)

Variable	1	2	3	4	5	6
1. Face 8m	-	-0.34 [-0.63, 0.01]	0.13 [-0.30, 0.53]	-0.18 [-0.57, 0.29]	0.22 [-0.18, 0.59]	-0.06 [-0.52, 0.39]
2. Fear 8m		-	0.02 [-0.44, 0.48]	-0.05 [-0.51, 0.41]	-0.15 [-0.58, 0.30]	0.05 [-0.45, 0.55]
3. Face 30m			-	-0.29 [-0.66, 0.17]	-0.14 [-0.55, 0.31]	0.37 [-0.13, 0.74]

4. Fear 30m	-	0.18 [-0.27, 0.60]	-0.13 [-0.58, 0.37]
5. Face 60m		-	-0.30 [-0.65, 0.14]
6. Fear 60m			-

DISCUSSION

In this study, we report novel data on the developmental changes and stability of attention disengagement and the well-established attentional bias towards faces vs. non-face patterns (i.e., face bias), as well as fearful relative to happy and neutral faces (i.e., fear bias), across early childhood. We used an overlap paradigm with faces (i.e., neutral, happy, fearful) and non-face control stimuli as central stimuli and geometric shapes as lateral stimuli to study attention disengagement probability (DP), and to derive estimates of face and fear biases.

At the level of the whole sample, the DPs increased in every face condition from 8 to 30 months but then declined again from 30 to 60 months. Thus, the children disengaged less frequently from faces to distractors at 8 vs. 30 months, and more frequently at 30 vs. 60 months. These age effects were specific to faces between 8 and 30 months: the slope of change was significant in each face condition but not in the non-face control condition. Between 30 and 60 months, changes were observed in all stimulus conditions. This pattern is consistent with the notion that dissociable attention mechanisms may be responsible for face and pattern processing (Peltola et al., 2018; Pyykkö et al., 2019) and the two may follow differential developmental trajectories during early childhood. The face bias followed a quadratic developmental trajectory with a clear decline between 8 and 30 months and no significant change thereafter, although the point estimates showed an increase in this bias between 30 and 60 months. The fear bias declined steadily from 8 months to 60 months. No correlations were found in the magnitude of the face bias between 8 and 30 months, or 30 and 60 months. A weak positive correlation was found for face bias between 8 and 60 months. There were no correlations in the magnitude of the fear bias across the three assessment points.

The overlap paradigm has been used in several infant studies to assess attention disengagement from different facial expressions, including fear, and non-face control stimuli. Our findings are consistent with previous longitudinal studies using the overlap paradigm with non-emotional (Nakagawa & Sukigara, 2013) as well as emotional (Peltola et al., 2018) stimuli. Generally, these studies have shown age-related changes in the overall probability of attention disengagement between infancy and toddlerhood (i.e., increases in disengagement probabilities or decreases in saccadic latencies to disengage and shift attention to a peripheral stimulus). Our results show a similar change between 8 and 30 months, but with a longer follow-up than that in the previous studies, our study provides novel evidence for a potential U-shaped developmental pattern in disengagement (i.e., an increase between 8 and 30 months and a decrease between 30 and 60 months) and a quadratic trend in the bias for faces across early childhood (i.e., a decline in face bias between 8 and 30 months and a non-significant increase in this bias between 30 and 60 months). Interestingly, there was no evidence for a similar pattern in the fear bias. This bias, typically high during infancy, decreased consistently over time at group level.

What underlies these age-related changes is not known, but several mechanisms may contribute to the changes in the saliency of social vs. non-social information as well as fearful vs. non-fearful facial expressions across early childhood. First, there may be continuous age-related changes in oculomotor and attentional control: as children develop, their oculomotor control improves and they may become less susceptible to “failure to disengage” (e.g., Hunnius et al., 2006). Although it is possible that such processes contributed to age-differences in the current study, the overall pattern of results is clearly not consistent with a continuous linear improvement in attention disengagement (e.g., the fact that the increase in disengagement was seen between 8 and 30 months, but not between 30 and 60 months).

Thus, a second possibility is that the mechanisms that underlie age-related changes in attention disengagement from faces are more specific to certain age and are not necessarily continuous over time in early childhood. There may be factors that increase attentiveness to facial information in infancy, but cease to do so or are less influential at later ages. For example, attention to faces may be the primary means through which the infant can discriminate familiar from unfamiliar individuals and learn about their physical and social environment before other means of communication (language) develop (Leppänen & Nelson, 2009; Sorce et al., 1985). Human infants begin to locomote (crawl) and express various forms of fear- and attachment-related behaviors during the second half of the first year (e.g., fear of heights and strangers, Braungart-Rieker et al., 2010). The onset of these behaviors may increase the salience of social information and, in particular potential danger-alerting cues such as fearful facial expressions (Braungart-Rieker et al., 2010; Leppänen & Nelson, 2009). Direct evidence linking infant social, motor or attachment-related behaviors to attention to faces is lacking, but results from prospective longitudinal studies support this notion: delayed disengagement from faces compared to non-faces at 7 months predicts prosocial behavior at 24 months (i.e., spontaneous helping, (Peltola et al., 2018) and delayed disengagement from fearful compared to happy/neutral faces predicts increased odds of secure attachment at 15 months (Peltola et al., 2015).

In addition to the group-level developmental changes, we examined individual variations in DPs and bias scores. Our results showed that estimates of DPs for individual children have low to moderate split-half reliability in infancy, but there is little longitudinal stability in these measures from infancy to mid childhood. The difference or bias scores were generally less reliable. Overall, these results are consistent with previous studies in showing that measures of attentional bias, which typically require a difference score to be calculated from two constituent scores, tend to have negligible reliability (see Kappenman et al., 2014 for similar results in adults). As a potentially interesting exception, the current results show that the bias for faces had some internal stability at 8 months and was weakly correlated with the face bias at 60 months.

Although measurement error may attenuate the estimates of longitudinal stability in attention disengagement (DP), it may not be the only reason for the lack of associations. The internal stability of DPs was moderate in the current study and previous studies using similar methods have shown that DPs have moderate test-retest stability in infancy (Leppänen et al., 2015). Thus, it is possible that the lack of stability in DPs may also reflect a “true” lack of association in attention disengagement processes over time. Attention control networks undergo rapid developmental changes during the first years of life. During infancy, the control of attention depends primarily on the orienting attention network reacting to sensory events, whereas by age 3–4 years the executive attention network starts to exert control over the orienting responses enabling the selection among competing responses (Posner et al., 2012). Thus, the switch in the dominance between these control networks may contribute to the weak stability of attention disengagement patterns in the overlap paradigm. There may also be developmental changes in the perceived salience of social cues. The saliency of the faces of conspecifics is high during infancy in both humans and other primates (Leppänen & Nelson, 2012) but may reduce during the second and the third year at the time of intense motor development and active exploration of the environment. The maturation of the executive attention network at 3–4 years of age, may again lead to heightened face preference as one of its functions is to extract meaning from the visual stimuli, and also inhibit orientation responses if the stimulus is deemed salient (Nakagawa & Sukigara, 2013).

Individual differences in attention control can be further studied using a wider range of statistical approaches (e.g., person-centered approaches such as Latent Profile Analysis, LPA) to examine if there are subgroups of children showing stable, entrenched attention patterns such as continuously high or low face or fear bias. These subgroups may be informative when trying to understand deviant attention development leading for instance to high anxiety (Vallorani et al., 2021) or low empathy and high callousness (Peltola et al., 2018). Further, it will be interesting to use variable-centered approaches using information from multiple tasks of face and fear processing to identify variables across tasks indicating typical vs. deviant development of face and fear processing (Vallorani et al., 2021).

In addition to its main findings, our study showed that attention to neutral vs. happy faces may change across age. DPs for neutral faces were comparable to DPs for happy faces at 8 months, but DPs for neutral faces dropped relative to happy faces, and at 60 months DPs for neutral faces were similar to those for fearful faces. This result has implication for the interpretation of our findings. Following previous studies with infants, fear bias was calculated by comparing DPs for fear to the average DP in the happy and neutral face conditions. This approach has been justified in infant samples where the level of DPs is typically comparable between the happy and neutral conditions (see e.g., Leppänen, Cataldo, Bosquet Enlow, et al., 2018; Peltola et al., 2018). However, based on our findings at 30 and 60 months, combining neutral and happy into one "non-fearful" face condition may not be preferable. Indeed, Marusak et al. (2017) noted that older children (6–17 years) rated neutral (particularly adult) faces as negative similarly to angry faces. Also, there was a lack of age-related decrease in reaction times when rating neutral faces indicative of the salience of the neutral faces across childhood development. Based on these findings, it may be advisable to contrast different face conditions (i.e., neutral, happy, and fearful faces) to a non-face control condition instead of neutral faces to study attention biases beyond infancy.

In conclusion, our results replicate previous studies in showing that attention disengagement increases in the face-distractor overlap paradigm from infancy (8 months) to toddlerhood (30 months). However, as a novel finding our study with an extended follow-up shows that this increase does not continue between 30 and 60 months. Thus, attention disengagement pattern in face processing may follow a U-shaped trajectory (see also Libertus, Landa, & Haworth, 2017 for a comparable result in a sample of 3 to 36-month olds). The face bias shows comparable U-shaped development whereas the fear bias, which is typically high during infancy, shows a declining developmental pattern. We did not find stability in the fear bias across the follow-up whereas the face bias correlated positively and weakly between 8 and 60 months suggesting some stability in this very fundamental social-emotional trait.

Limitations

A key strength of our study was that the same overlap paradigm was used in three different assessment points across early childhood. However, the paradigm has been designed to capture infant attention biases for faces and fear (Leppänen, 2016) and it has been very little used in the current format to assess attention biases in older children, although research with adults has used active disengagement tasks to assess attentional biases for emotional cues (Georgiou et al., 2005). Relatedly, we also made modifications to the distractors with increasing age; in infancy the distractors were static, at 30 months they were flashing on and off, and at 60 months they started to flash after the child directed attention towards it (see also Leppänen, Cataldo, Enlow, et al., 2018; Peltola et al., 2018). This may have affected the results. It may be argued, however, that if there was any effect of distractor type on DPs, this effect would have been similar across the face and non-face, resulting in a main effect of age on DP and not the observed pattern of differential effects in the face and non-face conditions. In this context, it is also important to note that, as the current eye-tracking task was always performed as the first task of the visit, the age-related changes cannot be attributed to potential order effects within a testing session (e.g., a carry-over effect of a previous task on the current task). A longer version of the overlap paradigm was used at 8 months than at 30 and 60 months (24 trials) as compared to 8 months (48 trials) due to the increase in the number of eye-tracking paradigms in the follow-up sessions. The low number of trials in individual conditions may have attenuated the stability estimates for individual children, particularly with respect to measures calculated from DPs in single stimulus conditions, such as the bias for fearful faces. Finally, our study is limited by the fact that it focused on age related changes in one aspect of attention (disengagement) and one paradigm (spatial overlap). Previous studies suggest that individual variations in attentional biases for faces generalize across paradigms in infants (Gillespie-Smith et al., 2016). Also, a decline in attention to eyes vs. mouth has been reported from infancy to mid childhood (Nishizato et al., 2017), but it remains open as to whether the developmental time-course of other aspects of attention orienting to faces vs. objects is similar to that reported in the current study.

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