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Bi-directional relations between attention and social fear across the first two years of life☆

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ABSTRACT

This study examined longitudinal relations between attention and social fear across the first two years of life. Our sample consisted of 357 infants and their caregivers across three sites. Data was collected at 4, 8, 12, 18, and 24 months of age. At all 5 assessments, the infants participated in 2 eye-tracking tasks (Vigilance and Overlap) which measured different components of attention bias (orientation, engagement, and disengagement), and parents completed questionnaires assessing infant temperament. For the first three assessments, social fear was measured using the Infant Behavioral Questionnaire-Revised (IBQ-R; Gartstein & Rothbart, 2003) focused on interactions with strangers, and for the final two time points, we used the social fearfulness subscale on the Toddler Behavior Assessment Questionnaire (TBAQ; Goldsmith, 1996). The results of a random intercept cross-lagged panel model showed intermittent evidence of uni-directional and reciprocal relations between attention to both threatening and positive emotion facial configurations and social fear. Our findings suggest that characteristics of behaviorally inhibited temperament–in this case, social fear–begin to interact with attention biases to emotion in the very first year of life, which carries implications for the timing of future interventions designed to mitigate the early development of maladaptive patterns of attention.

1. Introduction

1.1. Attention to threat

Attention bias to threat has been conceptualized in many ways over the past several decades. Generally, it indicates an increased sensitivity to potentially threatening stimuli in the environment, and is often measured by faster detection of, longer looking to, or difficulty disengaging from, angry or fearful facial configurations when compared to happy or neutral stimuli (Burris & Oleas, 2019). Given the adaptive benefits of quickly detecting and responding to threat, researchers have suggested that attention biases to threat are evolutionarily adaptive, automatic, and part of typical development (LeDoux, 1995; Petersen & Posner, 2012; Williams et al., 1998).

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Although previous research has demonstrated that attention biases for stimuli like angry or fearful facial configurations are early developing, emerging as early as 7 months of age (Kotsoni et al., 2001; Peltola et al., 2008), we know very little regarding patterns of change over time. For example, some research demonstrates a stable pattern of attention bias to threat that develops between 4 and 24 months (Morales, et al., 2017a), while other studies point to normative changes in attention biases as a function of age (Leppänen et al., 2018; Peltola et al., 2018). Further, research from the clinical literature suggests that attention biases to threat may not necessarily be part of typical development, but rather markers of risk for the development of anxiety (Bar-Haim et al., 2007; Britton et al., 2012; Burris, Buss et al., 2019; Morales et al., 2016), particularly within the context of additional risk factors, such as temperamental fearfulness, or behavioral inhibition (Pérez-Edgar et al., 2010).

1.2. Behavioral inhibition

Most of the literature on temperamental risk for anxiety focuses on behavioral inhibition (BI). BI is a temperament style characterized by the tendency to experience distress in response to novel stimuli (including people, places, and objects), hypersensitivity to changes in the environment, and engagement in avoidant coping behaviors (Kagan et al., 1984). Manifestations of BI encompass several domains, including motivations (withdrawal or avoidance) or behavioral reactions (flight or freezing) and social reactions (social fear or social reticence) to novelty (Buss, 2011). For example, toddlers with BI are more likely to show characteristics of social fear in childhood (Henderson et al., 2001), such as hesitation, wariness, and fearful behavior when engaging with an unfamiliar person, which in turn may put them at higher risk for social anxiety later in life (Rapee, 2014). Approximately 10–20% of children have a behaviorally inhibited temperament, which is relatively stable throughout development. Among those who are behaviorally inhibited in childhood, 30–50% remain inhibited into adolescence and adulthood (Buss, 2011).

1.3. Attention to threat and BI

Importantly, the developmental literature has demonstrated a link between BI and attention biases for threat (Morales et al., 2017b; Morales et al., 2015; Pérez-Edgar et al., 2011). For example, as early as 5 years of age, children who are temperamentally shy, and are thus at increased risk for the development of social anxiety, show a heightened attention bias for social threats (i.e., angry faces) when compared to non-shy controls (LoBue & Pérez-Edgar, 2014). Further, one study reported that while children who are behaviorally inhibited at ages 2 and 3 are socially withdrawn at age 5, this relationship was only significant for children who showed a heighted bias for angry versus happy faces (Pérez-Edgar et al., 2011). A second study reported a similar relationship in adolescents (Pérez-Edgar et al., 2010). Taken together, these findings suggest that a behaviorally inhibited temperament might interact with attention to threat to predict the development of anxiety symptoms.

However, some of the studies examining the relation between attention biases to threat and a fearful temperament have provided mixed results. For example, while some research has demonstrated a significant relation between fearful temperament and an attention bias away from, or avoidance of threat (Morales et al., 2015), other research has shown the opposite, such that behavioral inhibition predicted attention biases toward threat (Pérez-Edgar et al., 2011). To complicate things further, some studies simply found no relation between the two (Broren et al., 2011), while other research has found that childhood temperamental shyness was associated with *both* vigilance and avoidance (Morales et al., 2017b; Poole & Schmidt, 2021) rather than one or the other.

Unfortunately, most existing research on this topic consists of cross-sectional studies with infants, or longitudinal studies with older children and adults (White et al., 2017), limiting our understanding of how attention biases to threat develop over the first few years of life and whether they are linked to risk factors for anxiety related to social fear. Longitudinal studies early in infancy are needed to capture how patterns of biased attention to threat first develop, and whether they interact with individual difference factors to confer risk for anxiety over time. Field and Lester (2010) proposed three models to conceptualize how attention biases to threat might develop early in life and interact with environmental and individual difference factors. The integral bias model suggests that attention biases for threat are normative and stable over time, with very little room for developmental change. In contrast, the moderation model posits that biased attention to threat is normative but is *moderated* by individual factors like infant temperament. According to this model, individuals with a behaviorally inhibited temperament might maintain or show even greater biases compared to children without BI over the course of development. Finally, the acquisition model posits that attention biases to threat are not present at birth, but instead are *acquired* over the course of development through experience.

Although studies that explicitly test these models in infancy are limited, very recent work has begun to describe the typical trajectory of attention to both threatening and non-threatening emotions in the first two years of life. For example, one recent study reported that between 4 and 24 months of age, infants become faster to detect angry facial configurations and display greater engagement with, and less disengagement from, angry faces compared to neutral faces. Further, a significant bias for angry or threatening facial configurations over other emotional configurations did not emerge until 24 months of age (Reider et al., 2022). This suggests that attention biases for threat develop over the first two years of life, with a clear bias for threat emerging by age 2. These data provide support for both the acquisition and moderation models (but not the integral bias model) proposed by Field and Lester (2010), such that attention biases to threat were normative and developed over time. However, because the paper focused on capturing typical development, it did not address the role of potential moderators like behavioral inhibition or social fear, which are additional known risk factors for later social anxiety (Chronis-Tuscano et al., 2009).

Table 1
Demographic information.

Infant Race/Ethnicity								
White	Hispanic	African American	Multiracial	Asian	Not Reported			
180 (51%)	78 (22%)	58 (16%)	27 (8%)	9 (3%)	5 (1%)			
Parent Education								
	Grade School	High School	High School Degree	College/ Technical School	College Degree	Graduate School	Graduate Degree	Not Reported
Mother's Education	11 (3%)	17 (5%)	36 (10%)	57 (16%)	73 (20%)	58 (16%)	66 (19%)	39 (11%)
Father's Education	11 (3%)	15 (4%)	50 (14%)	60 (17%)	70 (20%)	42 (12%)	56 (16%)	53 (15%)
Annual Family Income								
Less than $15,000	$15,000 - $20,000	$21,000 - $30,000	$31,000 - $40,000	$41,000 - $50,000	$51,000 - $60,000	Greater than $60,000	Not Reported	
49 (14%)	20 (6%)	22 (6%)	16 (5%)	22 (6%)	29 (8%)	140 (39%)	59 (17%)	

1.4. The present study and hypotheses

Here we investigated how normative patterns of attention bias interact with social fear over the first two years of life. We chose social fear over other aspects of infant temperament because social fear most closely aligns with the core components of BI, such as fear and wariness in response to unfamiliar others, and social withdrawal and avoidance behaviors (Buss, 2011; Kagan et al., 1984). Further, research has demonstrated continuity in development from temperament in infancy to BI and social fear in childhood, and later social anxiety in adolescence and adulthood (Askew, et al., 2015; Pérez-Edgar & Guyer, 2014). Thus, while the literature on BI has informed our hypotheses, here we focused on a parent-report measure of social fear.

We investigated our research question among a diverse and longitudinal sample of infants who, as part of a larger study, participated in two eye-tracking tasks at 5 assessments (4, 8, 12, 18, and 24 months). Additionally, infant temperament was measured via caregiver report at each assessment. We chose two eye-tracking tasks to capture attention bias for the current investigation using metrics most evident in the literature, typically either rapid fixations to threatening stimuli (orientation) or longer looking at (or slower disengagement from) threatening stimuli—in most cases, angry facial configurations, as they are a direct signal of social threat (Leppänen et al., 2018; LoBue & DeLoache, 2010; Nakagawa & Sukigara, 2012; Peltola et al., 2018). Engagement and disengagement, in turn, is embedded within several interacting attention networks (Corbetta & Shulman, 2002; Petersen & Posner, 2012; Rothbart et al., 2011). The *alerting* network detects information in the visual field and is responsible for selective attention and detection of novel stimuli (Sturm & Willmes, 2001). The *orienting* network is responsible for the selection and prioritization of information in the environment, including disengaging, shifting, and reengaging with visual stimuli (Posner & Cohen, 1984). While these systems are functional early in life and are both assessed in the attention bias literature, little work has considered how they might uniquely impact socioemotional development.

As such, here we examined the alerting network, or rapid detection of emotional stimuli, with a Vigilance task (Fu et al., 2020), and the orienting network, or prolonged engagement with and difficulty disengaging from emotional stimuli, with a classic Overlap task (Morales et al., 2017a; Peltola et al., 2008; Vallorani et al., 2021, 2022). In the Vigilance task, infants were presented with a single stimulus—either a happy, angry, or neutral facial configuration—in one of the four corners of a screen, and we measured how quickly infants detected each target. Rapid detection was indexed by time to first fixation to threatening (i.e., angry), happy, and neutral facial configurations. In the Overlap task, infants were presented with happy, angry, or neutral facial configurations in the center of a screen, and shortly after their appearance, a checkerboard probe appeared simultaneously to the left or the right of the facial stimulus. To index engagement, we measured total looking to the facial stimuli while the probe was present, and to index disengagement, we measured total looking to the probe while the face was present. We then used these data in cross-lagged longitudinal models to discern how different components of attention to various emotional facial configurations (angry, happy, and neutral) and social fear influence one another over time.

There are several possible hypotheses. One is that there will be no relation between attention to threat and social fear over time in this young age group. Another is that attention to threat at earlier assessments will predict social fear at later assessments, suggesting that attention bias to threat is prospectively related to social fear, in line with previous work (Van Bockstaele et al., 2014). Alternatively, it is also possible that social fear at earlier assessments will predict attention bias to threat at later assessments, suggesting that social fear is prospectively related to a bias for threatening facial configurations. One final possibility is that the relation between attention to threat and social fear is reciprocal over time, such that social fear at one time point would predict attention to threat at the next time point and vice versa.

2. Materials and methods

2.1. Participants

The participants were part of a larger, ongoing longitudinal study ($N = 357$) exploring the development of attention and temperament during the first two years of life (Pérez-Edgar et al., 2021) . Participants were recruited through local baby registries (40%), university-sponsored participant databases (13%), community-level recruitment strategies (38%), and word-of-mouth (10%).

Prospective families were contacted by letter, email, or phone explaining the motivations and methods of the study. Infants and their caregivers were enrolled when the infants were 4 months of age ($N = 298$; 147 females), with an additional 46 participants enrolled at 8 months (27 females), and 13 participants at 12 months (7 females), for a total enrollment of 357 infants in the full sample (181 females). The Institutional Review Boards at the Pennsylvania State University and Rutgers University approved all procedures and parents provided written consent and were compensated for their participation. Table 1 presents demographics for the final sample.

2.2. Measures

2.2.1. Questionnaires

In most cases, the following questionnaires were administered via Qualtrics before each laboratory visit, although some were administered during the laboratory visit (e.g., for participants who did not have access to a computer, tablet, or smartphone), and others were completed after the laboratory visit. Versions of each questionnaire were available in both English and Spanish and were administered based on the caregiver's first language.

2.2.1.1. Infant Behavior Questionnaire—Revised (IBQ-R). The IBQ-R is a 191-item survey designed to assess general patterns of behavior associated with temperament in infancy (3–12 months) (Gartstein & Rothbart, 2003; Parade & Leerkes, 2008; Putnam et al., 2014). Parents rated how often they observed a behavior in the past week at the 4-, 8-, and 12-month assessments. Each item describes an infant's behavior (e.g., During feeding, how often did the baby lie or sit quietly?) using a 7-point Likert scale (never, very rarely, less than half the time, half the time, more than half the time, almost always, always). Parents are also given a "not applicable" response option for use when the infant has not been observed in the situation described. Each item loads onto one of 14 subscales: Activity Level, Distress to Limitations, Fear, Duration of Orienting, Smile/Laughter, High-intensity Pleasure, Low-intensity Pleasure, Soothability, Falling Reactivity, Cuddliness, Perceptual Sensitivity, Sadness, Approach, and Vocal Reactivity. Items from each subscale are averaged to obtain scale scores. Each scale, in turn, loads onto one of three broader factors (Surgency, Negativity, Orienting/-Regulation). The IBQ-R has demonstrated good internal consistency, reliability, and validity, including correlations with laboratory observations (Gartstein & Marmion, 2008; Goldsmith & Campos, 1990; Parade & Leerkes, 2008).

Because the IBQ's fear subscale encompasses distress in response to novel, social, or physical stimuli, it captures components of fear outside of our targeted variable of social fear. To address this, we followed Goldsmith's (1996) recommendation of using five items on the fear subscale that focus specifically on infants' response to strangers (more details below).

2.2.1.2. Toddler Behavior Assessment Questionnaire (TBAQ). The TBAQ is a 120-item survey designed to assess general patterns of behavior associated with temperament in young children (2–3 years), and was collected at the 12-, 18-, and 24-month assessments (Goldsmith, 1996). Parents rated how often their toddler displayed a specific behavior in the past month using a 7-point Likert scale (1 =never, 2 =very rarely, 3 =less than half the time, 4 =half the time, 5 =more than half the time, 6 =almost always, 7 =always). Each item loads onto one of 11 subscales (Activity Level, Anger, Appropriate Attention Allocation, Inhibitory Control, Interest, Object Fear, Perceptual Sensitivity, Pleasure, Sadness, Social Fear, Soothability). Items from each subscale are averaged to obtain scale scores.

2.2.1.3. Social fear measurement in present study. Goldsmith (1996) reported high levels of convergence with various subscales of the IBQ and TBAQ; however, the IBQ's Fear subscale ($\alpha = 0.90$) and the TBAQ's Social Fear subscale ($\alpha = 0.87$) are not directly comparable because the IBQ subscale encompasses fear of social and non-social stimuli. Goldsmith and others (Brooker et al., 2013; Goldsmith, 1996) have accounted for this difference by using the 5-item mini-scale from the IBQ ($\alpha = 0.90$) and the Social Fear subscale from the TBAQ, making them more conceptually similar and quantitatively comparable ($r = 0.68$, $p < .01$ at 12 months in our sample). Items on the IBQ mini-scale asked parents to report how their infants responded to strangers over the past 2 weeks (e.g., When introduced to an unfamiliar adult, how often did the baby cling to a parent?; When introduced to an unfamiliar adult, how often did the baby never "warm up" to the stranger?). Items on the TBAQ Social Fear subscale reflected age-appropriate social interactions involving unfamiliar others (e.g., When first visiting a babysitting co-op, daycare center, or nursery, how often did your child cry when not being held by her/his parent and resist being put down?; When one of the parents' friends who did not have daily contact with your child visited the home, how often did your child talk much less than usual?).

Both the IBQ and TBAQ were administered at the 12 month assessment. Because there was less missing data from the IBQ and there were no statistical differences in social fear between the two measures, we used data from the IBQ at the 4, 8, and 12 month assessments and the TBAQ at the 18, and 24 month assessments in our analyses.

2.2.2. Eye-tracking

Eye-tracking data were collected across sites using SMI eye-tracking systems, either the SMI RED or REDm system, both offering comparable specifications/capabilities (SensoMotoric Instruments, Teltow, Germany). Participants were seated ~60 cm from a 22″ Dell monitor for stimulus presentation, in a highchair. If needed, infants could also sit on their parent's lap or on the lap of an experimenter. Gaze was calibrated using a 5-point calibration followed by a 4-point validation, using an animated flower on a black screen and infant-friendly music. Gaze data were sampled at 60 Hz and collected by Experiment Center (SensoMotoric Instruments, Teltow, Germany). Infants/toddlers were calibrated below 4° of visual angle from all calibration points.

2.2.2.1. Vigilance task. Eye-tracking data were collected during an infant Vigilance task to assess infants' ability to detect, or orient to,

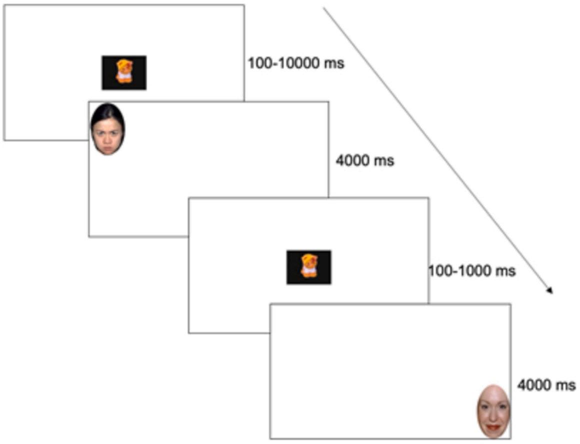


Fig. 1. Vigilance task. Adult faces were sampled from the NimStim face set (Tottenham et al., 2009) and appeared for 4000 ms. Each trial continued with a random presentation of a face stimulus in one of the four corners of the screen.

emotional faces (Fu et al., 2020; see Fig. 1). The task had 90 trials, with each trial beginning with a randomly presented fixation-dependent attention getting Baby Sensory animated video with a black background and classical music dubbed in. Each trial was initiated when the infant's attention was on a video clip presented centrally on the screen, which was triggered either when the infant fixated for at least 100 ms or when the experimenter determined that the infant was looking at the video clip. If the participant did not attend to the center of the screen, the slide advanced after 10,000 ms. Each trial continued with a random presentation of an adult face stimulus in one of the four corners of the screen. Faces were sampled from the NimStim face set (Tottenham et al., 2009) and appeared for up to 4000 ms or until the participant fixated it for 100 ms. Ten adult actors (5 male) provided neutral, happy, or angry, closed mouth images. Facial stimuli were approximately 9.50 cm × 6.50 cm, and the visual angle of each face was 9.05° (H) x 6.20° (W). Faces were approximately 16.59° visual angle from the center. No face stimuli appeared in the same location consecutively, and the order of face stimuli was randomized across participants. Location of the faces was counterbalanced across the four corners of the screen. There were 4000 ms white screens that were shown after every 7th trial to minimize habituation and predictive looking. Task design and recording were completed by Experiment Center (SensoMotoric Instruments, Teltow, Germany).

The raw (X, Y) position of fixations was exported from BeGaze (SensoMotoric Instruments, Teltow, Germany). An area of interest (AOI) encircling and including the entire face stimulus was created and exported from BeGaze. A 2 cm "error margin" was added to each ellipse, to account for deviation permitted in the calibration procedure. Data processing was restricted to gaze data within the face AOI. An in-house processing script was written in R version 3.6.2 (R Development Core Team, 2019) to measure latency to fixate the face AOI on each trial.

2.2.2.1.1. Data pre-processing. Metrics were cleaned on a trial-by-trial level. If a fixation was not detected to the face during a trial, that trial was not included in latency calculations. Furthermore, trials with anticipatory eye movements in which latency to fixate on the face was less than 200 ms were removed from the analysis (Canfield & Haith, 1991). After this cleaning, average and median latencies were calculated for each emotion. Finally, latencies were transformed from milliseconds to seconds.

2.2.2.1.2. Missing values/exclusions. Of the 357 infants enrolled in the study, 283 infants provided data on the Vigilance task for at least one time point. Participants were excluded from the analyses if they did not provide any data on the Vigilance task for at least one of the 5 assessments ($N = 74$). Participant data points were also excluded if they were outside the acceptable age range for each timepoint, defined as the midpoint between each successive timepoint ($N = 20$). Table S1 presents changes in sample based on these cleaning metrics.

Next, to assess the reliability of our data, the minimum number of trials to achieve a stable mean latency was determined using two metrics used in a previously reported analysis (described in Reider et al., 2022)), that were adapted from Goldsworthy and colleagues (2016) and Cuypers and colleagues (2014). Within each participant and for each assessment and type of emotion, the overall mean latency and its 95% bootstrap confidence interval were estimated. Then, the rolling average latency was computed for each trial (that is, the average latency including all trials up to the current trial). For each trial, we recorded (1) the percent difference from the overall mean latency; and (2) whether the rolling average was contained within the 95% confidence interval associated with the overall mean latency. Having done this for all participants, the minimum number of trials necessary to get a stable mean latency was determined as (1) the trial at which the percentage difference from the overall mean latency fell below 10% (on average) and (2) the trial at which the proportion of rolling average latencies that fall into the confidence interval reached 0.95. According to these metrics, ten trials was the minimum number to reach both criteria across all time points and emotions.

In line with these criteria, 404 (23%) participant data points for infants who attempted each task were excluded for having an insufficient number of trials (note 24 of these data points were also considered outliers). An additional 4 (<1%) participant data points were considered outliers, defined as more than 3 standard deviations from the mean for each emotion at each time point, and were removed. In the end 1382 participant data points were included in the analyses. Table S1 provides information about the final sample before and after these cleaning metrics.

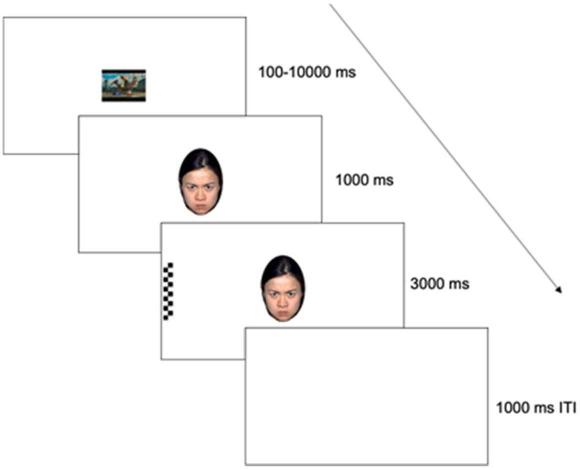


Fig. 2. Overlap task. Using the NimStim face set (Tottenham et al., 2009), infants first completed an initial fixation of 1000 ms, followed by an adult face presented centrally for 1000 ms, and then presented simultaneously with a peripheral checkerboard probe for 3000 ms.

2.2.2.2. Overlap task. Infants completed a version of a classic Overlap task (Morales et al., 2017a; Peltola et al., 2008) to assess infants' ability to engage with and disengage from emotional faces (see Fig. 2). Infants were presented with up to 30 experimental trials, ending either when all trials were completed or when the infant could no longer attend to the task. Each trial was initiated when the infant's attention was on a video clip presented centrally on the screen, which was triggered either when the infant fixated for at least 100 ms or when the experimenter determined that the infant was looking at the video clip. If the participant did not attend to the center of the screen, the slide advanced after 10,000 ms. Following was a central face sampled again from the NimStim face set for 1000 ms (Tottenham et al., 2009). Ten adult actors (5 male) provided neutral, happy, or angry, closed mouth images. Facial stimuli were approximately 12 cm x 8 cm and the visual angle of each face was 11.42° (H) x 7.63° (W). Following the presentation of the face, a checkerboard stimulus then appeared in either the left or right periphery of the screen adjacent to the face (20.78° visual angle) for 3000 ms. The checkerboard was 12 cm × 2.5 cm, 11.42° x 2.39° visual angle. This progression of stimuli was concluded with a 1000 ms ITI, which was a blank screen. No consecutive trials were identical in terms of face and probe placement.

Areas of interest (AOIs) were drawn as ellipses enclosing the face and rectangles enclosing the checkerboards. A 2 cm "error margin" was added to each ellipse, to account for the deviation permitted in the calibration procedure. Analyses were based on gaze to these designated AOIs. Fixations, defined as gaze maintained for at least 80 ms within a 100-pixel maximum dispersion, were extracted with BeGaze (SensoMotoric Instruments, Teltow, Germany). All other computations of gaze metrics were performed using in-house R scripts.

We computed dwell to the central face while the checkerboard stimulus was present (engagement), mirroring the analysis conducted by Morales and colleagues (2017a), and dwell to the checkerboard while the face was present (disengagement). For base processing, dwell is defined as the duration of fixations as well as saccades within the designated AOI while the probe was present. Averages of these values for all trials in which gaze was tracked were generated for each emotion.

2.2.2.2.1. Data pre-processing. Metrics were cleaned on a trial-by-trial basis. If a fixation to the checkerboard stimulus was not detected during a trial, the trial was not included. Further, trials with anticipatory eye movements in which latency to fixate the checkerboard probe was less than 200-ms were also removed from the analysis (Canfield & Haith, 1991). Our engagement variable was defined as total looking to the facial stimuli while the probe was present, and our disengagement variable was defined as total looking to the probe while the face was present. Finally, all values were transformed from milliseconds to seconds exactly like the Vigilance task.

2.2.2.2.2. Missing values/exclusions. Of the 357 infants enrolled in the study, 278 infants provided data on the Overlap task for at least one time point. Participants were excluded from the analyses if they did not provide any data on the Overlap task for at least one of the five assessments ($N = 79$). Participant data points were also excluded if they were outside of the acceptable age range for each timepoint, defined by the midpoint between each successive timepoint ($N = 3$).

To determine the minimum number of trials needed for each analysis, we again adapted a method from Goldsworthy and colleagues (2016) and calculated a threshold for the minimum number of trials infants needed to be included in the analyses for each outcome measure, as in previous analyses (Reider et al., 2022). Our analysis determined that infants needed to provide data on at least 6 trials for looking to the probe and 7 trials for looking to the face for the data to be considered reliable. Based on this criteria, 315 (18%) data points for infants who attempted the task were excluded for having an insufficient number of trials (note that 25 (1%) data points were also considered outliers, defined as more than 3 standard deviations from the mean for each emotion at each assessment). In the end, 1416 participant data points were included in the looking to the face analyses. Tables S2–S3 present changes in sample based on these cleaning metrics for engagement and disengagement.

Table 2
Results across final models, organized by attention measure, emotional facial configuration, and model fit.

Model	Variables	χ^2	*p*	χ^2/df	RMSEA	90% CI	CFI	TLI	Fit
Model 1	Orienting to Angry	χ^2 (23) = 33.80	0.07	1.46	0.037	.000 – 0.062	0.948	0.899	good
Model 2	Orienting to Happy	χ^2 (21) = 27.90	0.14	1.32	0.031	.000 – 0.059	0.966	0.928	good
Model 3	Engagement with Happy	χ^2 (23) = 42.907	0.00	1.86	0.050	.026 – 0.073	0.906	0.816	good
Model 4	Engagement with Neutral	χ^2 (21) = 33.316	0.04	1.58	0.042	.008 – 0.067	0.94	0.87	good
Model 5	Disengagement from Angry	χ^2 (21) = 28.01	0.14	1.33	0.032	.000 – 0.060	0.966	0.928	great
Model 6	Disengagement from Happy	χ^2 (21) = 31.75	0.06	1.51	0.039	.000 – 0.067	0.948	0.889	good
Model 7	Disengagement from Neutral	χ^2 (23) = 37.88	0.03	1.64	0.044	.015 – 0.068	0.924	0.851	poor

Table 3
Descriptive statistics in final models across assessment. Eye-tracking metrics are reported in seconds.

	4-Month Assessment		8-Month Assessment		12-Month Assessment		18-Month Assessment		24-Month Assessment	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Social Fear	2.17	1.29	3.07	1.52	3.86	1.53	3.79	1.05	3.71	1.05
Orienting										
Angry (Model 1)	0.67	0.21	0.51	0.15	0.51	0.14	0.49	0.14	0.48	0.11
Happy (Model 2)	0.65	0.21	0.52	0.15	0.48	0.14	0.52	0.14	0.52	0.11
Engagement										
Happy (Model 3)	1.48	0.72	1.57	0.55	1.47	0.50	1.54	0.61	1.26	0.57
Neutral (Model 4)	1.51	0.68	1.54	0.52	1.43	0.45	1.51	0.56	1.30	0.58
Disengagement										
Angry (Model 5)	0.18	0.19	0.20	0.15	0.13	0.10	0.16	0.14	0.18	0.18
Happy (Model 6)	0.14	0.17	0.17	0.15	0.14	0.11	0.16	0.16	0.16	0.14
Neutral (Model 7)	0.15	0.16	0.17	0.13	0.16	0.14	0.17	0.13	0.19	0.18

3. Results

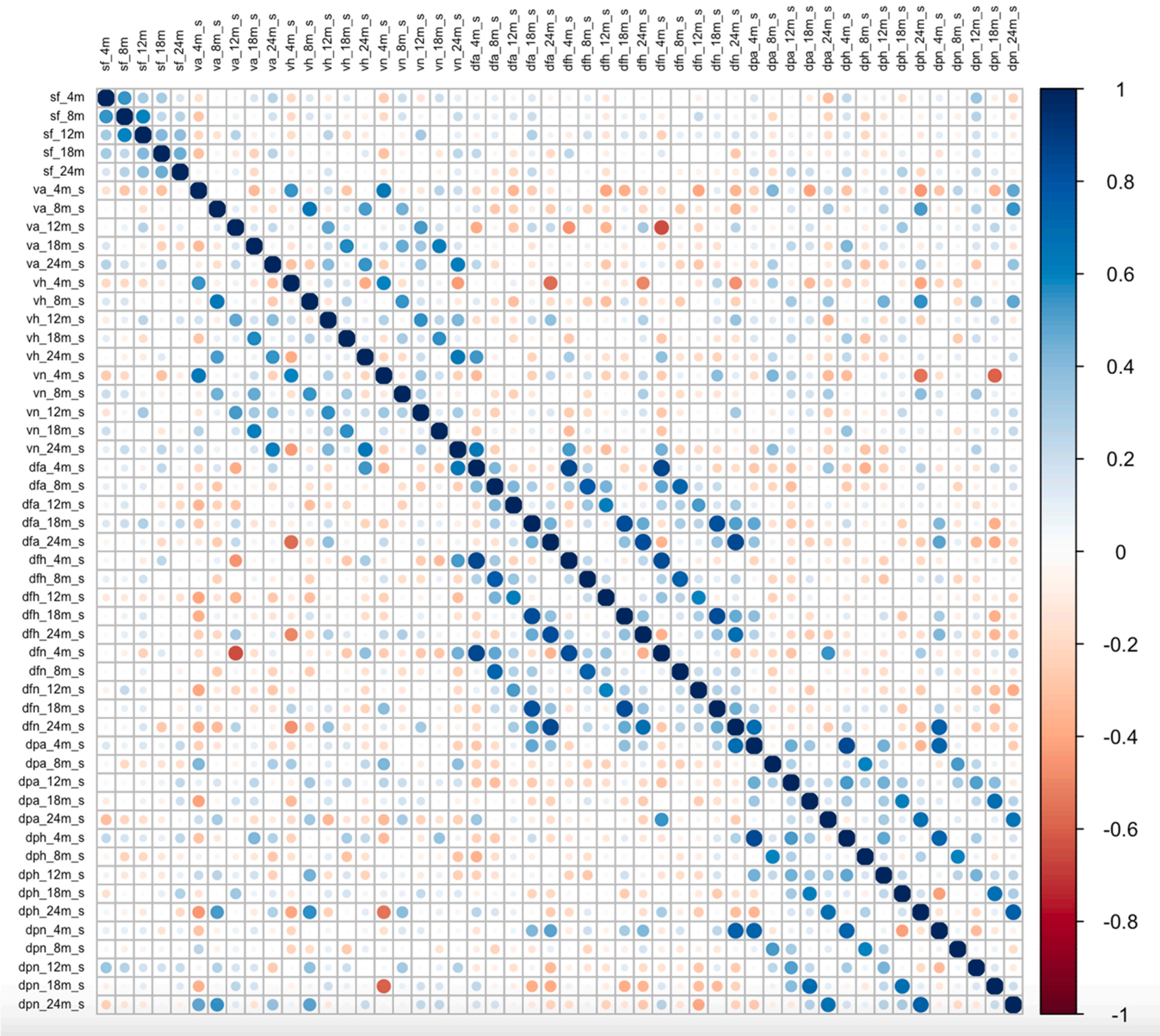
3.1. Overview

Our goal was to explore potential bi-directional relations between different components of attention (orientation, engagement, and disengagement) to various emotional configurations (angry, happy, and neutral) and social fear over time. To do so, we used a structural equation modeling framework to fit a random-intercept cross-lagged panel model (ri-clpm) for each outcome measure. Using an ri-clpm allows us to differentiate the variance accounted for by between-subject effects versus within-subject effects, in contrast to the traditional cross-lagged panel model which does not account for between-person stability (Hamaker et al., 2015).

The ri-clpm was conducted using Mplus version 8.7 (Muthén & Muthén, 2017). The maximum likelihood estimator was used, and model fit was assessed using conventional standards for the following measures: the chi-square (χ^2) value, the chi-square/df ratio test (< 3.0 = acceptable fit, < 2.0 = good fit), CFI and TLI (values >0.90 = acceptable and >0.95 = very good), and RMSEA (<0.08 = acceptable, <0.05 = good fit; (Bollen, 1989; Hu & Bentler, 1999). Patterns of missingness were considered missing at random based on a non-significant value for Little (1988) MCAR test $\chi^2(682) = 699.49$, $p = .313$ allowing us to use Full Information Maximum Likelihood (FIML) to account for missing data and optimize statistical power. Random intercept loadings were fixed at 1.00 and all other paths were freely estimated.

Here, cross-lagged, bidirectional paths were estimated between social fear and attention patterns (orienting, engagement, and disengagement) to emotional (angry, happy, and neutral) facial configurations across 5 assessments. The auto-regressive paths reflect within-person carryover effects from the previous assessment and the between-subject effects are reflected in two random intercepts: social fear and, depending on what aspect of attention the particular model focused on, orienting to emotional facial configurations (mean latency to fixate the face), engagement with emotional facial configurations (total looking time at the face while the probe was present), or disengagement from emotional facial configurations (total looking time at the probe while the face was present).

Table 4
Zero-order correlations between variables across all models.



Note. Variables are organized by outcome measure and assessment (**sf** social fear, **v**=latency to fixate emotional facial configurations on Vigilance task, **df**=dwell time to emotional facial configurations on Overlap task when probe is present (engagement), **dp**=dwell time to the probe on Overlap task when emotional facial configurations are present (disengagement)). For example, va_4m_s indicates latency to fixate angry facial configurations on the Vigilance task at the 4 month assessment, recorded in seconds.

3.2. Final models

Fit indices for the ri-clpms by emotion facial configuration (angry, happy, and neutral) and task are presented in Table 2 (models 1–2 tested orienting, models 3–4 tested engagement, and models 5–7 tested disengagement). Models that did not meet the accepted fit standards or resulted in improper solutions were not interpreted but can be found in Table S4 in the supplemental material.

The initial Orienting to Angry model (model 1) failed to converge due to very little variance in the latency to fixate angry facial configurations variable, resulting in negative variance (Heywood cases) and improper solutions. As such, the variance of that random intercept (RI-Orienting to Angry) as well as the covariance with the social fear random intercept (RI-Social Fear) were both fixed to zero (Usami & Hamaker, 2019).

Additionally, negative variance was identified in the engagement model that tested happy facial configurations (model 3) as well as the disengagement model that tested neutral facial configurations (model 7), resulting in improper solutions. We followed the same established protocol as above by fixing the variance of that random intercept and its covariance with the social fear random intercept to zero (Usami & Hamaker, 2019).

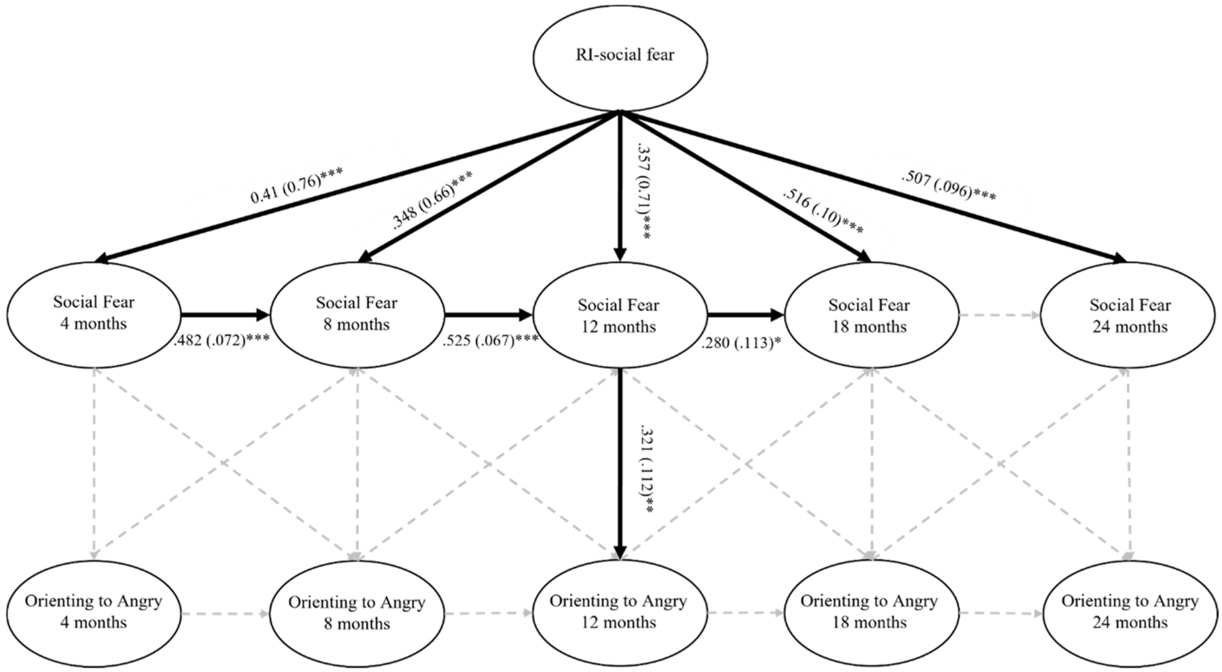


Fig. 3. Ri-clpm with social fear and average latency to fixate angry facial configurations on the Vigilance task (model 1). Values given are standardized coefficients and standard errors in parentheses. Black solid lines indicate a significant relationship between variables and grey dashed lines indicate non-significant paths (Note: * indicates $p < .05$, ** indicates $p < .01$., and *** indicates $p < .001$).

3.3. Descriptive Statistics and Correlations

Descriptives and zero-order correlations organized by task and emotion are listed in Tables 3–4. Overall, there was strong rank-order stability in social fear. At any given assessment, orienting to happy facial configurations was significantly correlated with orienting to angry facial configurations. Similarly, engagement with angry facial configurations was significantly correlated with engagement with happy and neutral facial configurations at any given assessment. Finally, we examined test-retest reliability for each of our outcome measures (social fear, orienting, engagement, and disengagement) by examining correlations for each between adjacent assessments (correlations can be found in Table 4).

3.4. Between-subject effects

Across all models estimated, there was no evidence of between-subject effects (between random intercepts), indicating that infant social fear was not related to attention to emotionally salient stimuli over time.

3.5. Orienting to facial configurations

3.5.1. Model 1–Latency to angry facial configurations

Due to little to no variance among latencies to angry facial configurations, the first model was estimated with social fear as the sole random intercept per Hamaker's (2015) recommendation of addressing this situation in ri-clpms. As such, between-subject effects were not estimated. At the within-person level, findings reflected strong autoregressive effects of social fear from 4 months to 18 months, but not between 18 and 24 months (see Fig. 3). Additionally, there were no significant within-person effects for latency to angry configurations. Importantly, greater deviations in social fear at 12 months were associated with greater deviations in latencies to angry facial configurations at 12 months. Finally, there was no evidence of bi-directional relations between social fear and latency to angry facial configurations. In sum, longitudinal relations for latency to fixate angry facial configurations were not present, and there was only one concurrent relation between the two outcome measures at the 12-month assessment.

3.5.2. Model 2–Latency to happy facial configurations

At the within-person level, there were strong positive autoregressive effects of social fear from 4 months to 18 months and negative effects of latency to happy configurations between 8 months to 12 months (see Fig. 4). The autoregressive effects were stronger for social fear compared to latency to happy configurations, indicating higher temporal stability for social fear. Additionally, there were no significant cross-lagged effects between the two outcome variables with one exception—infants who showed more deviations in latency to happy facial configurations at 12 months showed less deviations in social fear at 18 months. Taken together, these findings

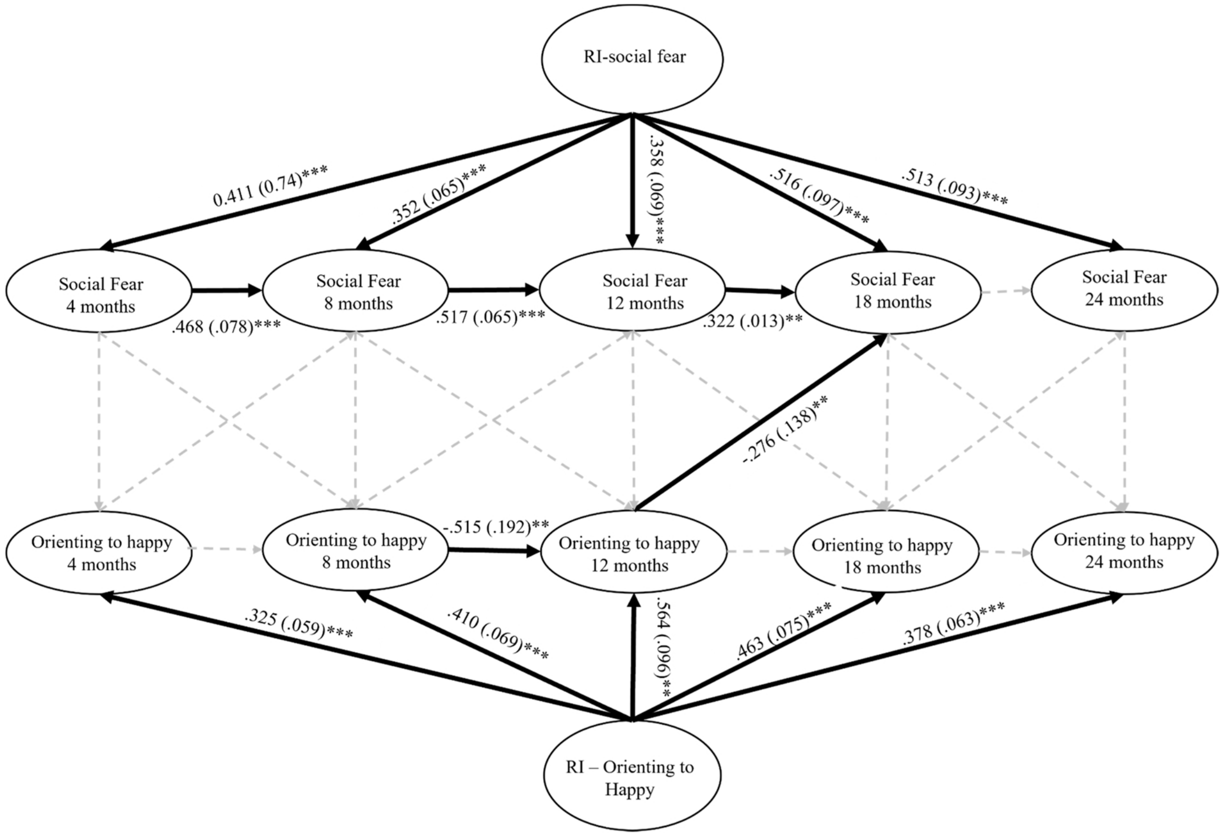


Fig. 4. Ri-clpm with social fear and orienting to happy facial configurations on the Vigilance task (model 2). Values given are standardized coefficients and standard errors in parentheses. Black solid lines indicate a significant relationship between variables and grey dashed lines indicate non-significant paths. Paths between random intercepts were not significant and omitted for visualization purposes (Note: * indicates $p < .05$, ** indicates $p < .01.$, and *** indicates $p < .001$).

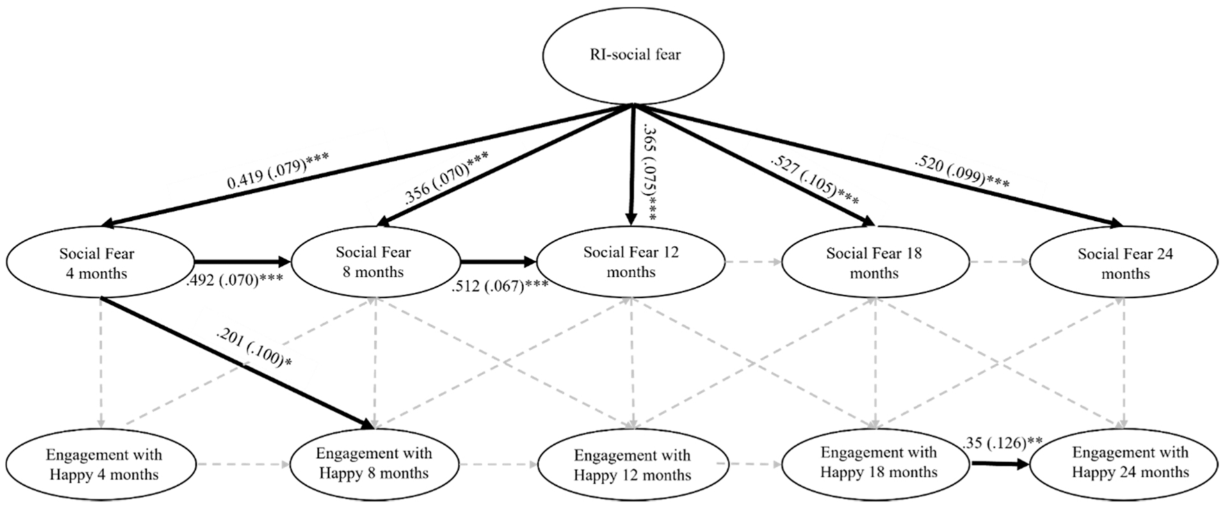


Fig. 5. Ri-clpm with social fear and engagement with happy facial configurations (model 3). Values given are standardized coefficients and standard errors in parentheses. Black solid lines indicate a significant relationship between variables and grey dashed lines indicate non-significant paths (Note: * indicates $p < .05$, ** indicates $p < .01.$, and *** indicates $p < .001$).

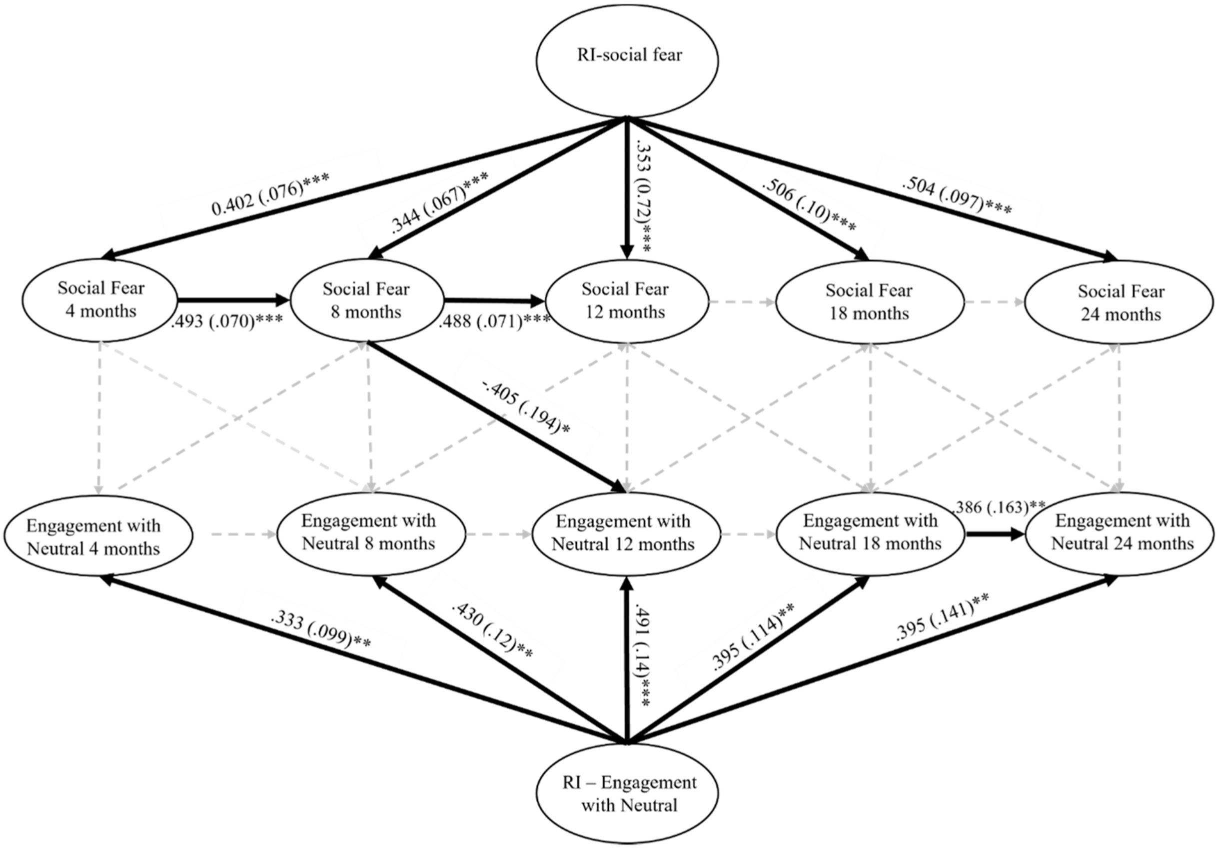


Fig. 6. Ri-clpm with social fear and engagement with neutral facial configurations (model 4). Values given are standardized coefficients and standard errors in parentheses. Black solid lines indicate a significant relationship between variables and grey dashed lines indicate non-significant paths. Paths between random intercepts were not significant and omitted for visualization purposes (Note: * indicates $p < .05$, ** indicates $p < .01$., and *** indicates $p < .001$).

suggest that deviations in latency to look at happy facial configurations were associated with later deviations in social fear, but only from 12 to 18 months.

3.6. Engagement

3.6.1. Model 3–Engagement with happy facial configurations

For social fear, there was evidence of within-subject effects for social fear from 4 to 12 months, but not for subsequent assessments (see Fig. 5). Additionally, there was evidence of within-subject effects for engagement with happy facial configurations, but not until later assessments, between 18 and 24 months. Additionally, there was a significant unidirectional relation between social fear at 4 months and engagement with happy facial configurations at 8 months. Taken together, although there was less temporal stability in our outcome variables compared to other models, prospective relations between social fear at 4 months and engagement with happy facial configurations at 8 months remained.

3.6.2. Model 4–Engagement with neutral facial configurations

There was a similar pattern in findings across both engagement models with evidence of temporal stability in social fear between 4 and 12 months, and engagement with neutral facial configurations between 18 and 24 months (see Fig. 6). Once again there was a single significant unidirectional relation, but in this case a negative relation between social fear at 8 months and engagement with neutral facial configurations at 12 months, indicating that increased stability in social fear at 8 months was associated with less stability in patterns of engagement with neutral faces at 12 months.

3.7. Disengagement

3.7.1. Model 5–Disengagement from angry facial configurations

There was evidence of within-subject effects for social fear across all assessments (see Fig. 7). Conversely, there was no evidence of

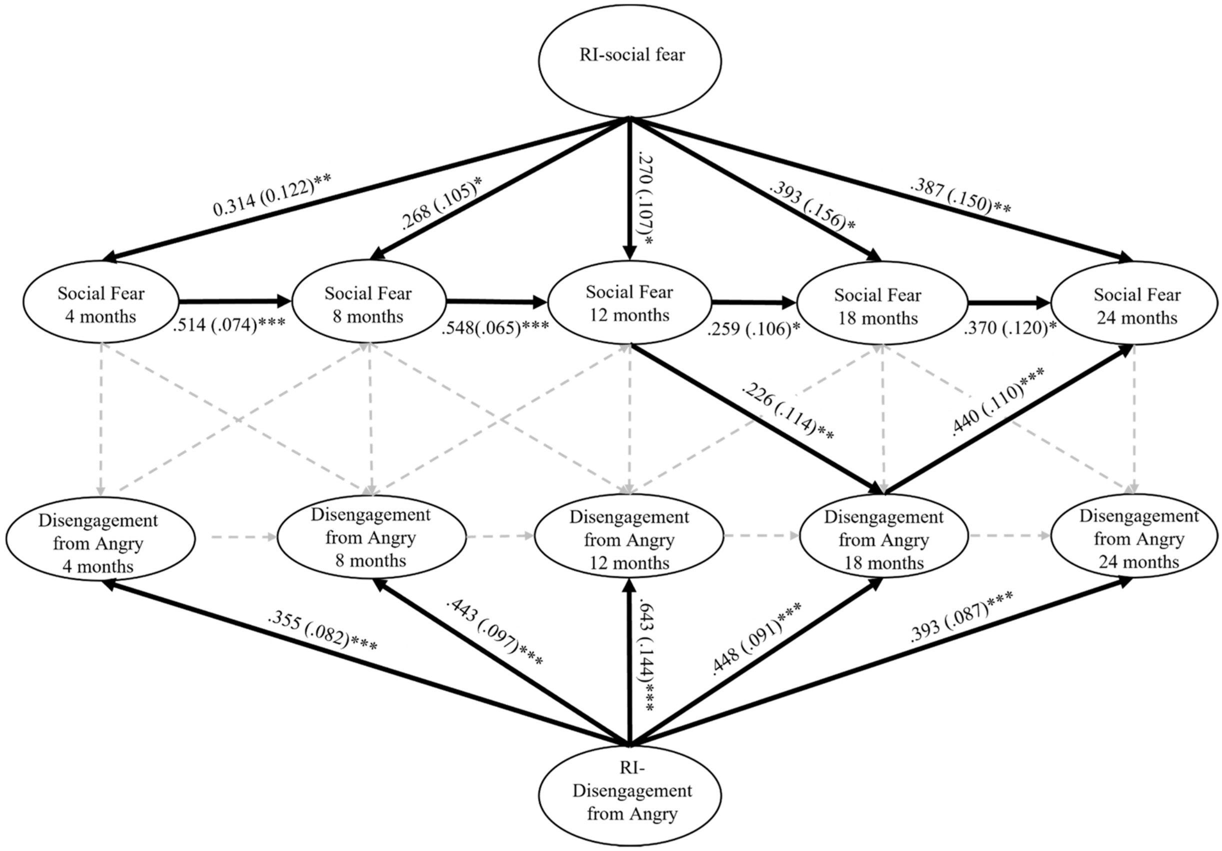


Fig. 7. Results from ri-clpm with social fear and disengagement angry facial configurations (model 5). Values given are standardized coefficients and standard errors in parentheses. Black solid lines indicate a significant relationship between variables and grey dashed lines indicate non-significant paths. Paths between random intercepts were not significant and omitted for visualization purposes (Note: * indicates $p < .05$, ** indicates $p < .01$., and *** indicates $p < .001$).

within-subject effects for dwell time to angry facial configurations. Finally, there were significant unidirectional effects present at the later assessments such that infants who deviated less in social fear at 12 months also deviated less in looking time to angry facial configurations at 18 months, which in turn was related to less deviation in social fear at 24 months. Collectively, these findings reflected the first indication of dynamic relations between social fear and looking to angry facial configurations during the second year of life.

3.7.2. Model 6–Disengagement from happy facial configurations

There was evidence of within-subject effects for social fear from 4 to 12 months, but not for subsequent assessments (see Fig. 8). There was no evidence of within-subject effects for disengagement from happy facial configurations. Similar to the previous models, a significant unidirectional relation between disengagement from happy facial configurations and social fear was present, but only between the last two assessments, 18 months and 24 months. Taken together, although there was less temporal stability in our outcome variables compared to other models, prospective relations between looking time to happy facial configurations at 18 months and social fear at 24 months remained present.

3.7.3. Model 7–Disengagement from neutral facial configurations

At the within-subject level, there was temporal stability in social fear across all assessments, from 4 months to 24 months, and none present for disengagement from neutral facial configurations (see Fig. 9). Finally, similar to our other disengagement models, there was a significant unidirectional relation between disengagement from neutral faces at 18 months and social fear at 24 months. Due to minimal variance in the neutral to facial configurations variable, social fear was the sole random intercept in this model.

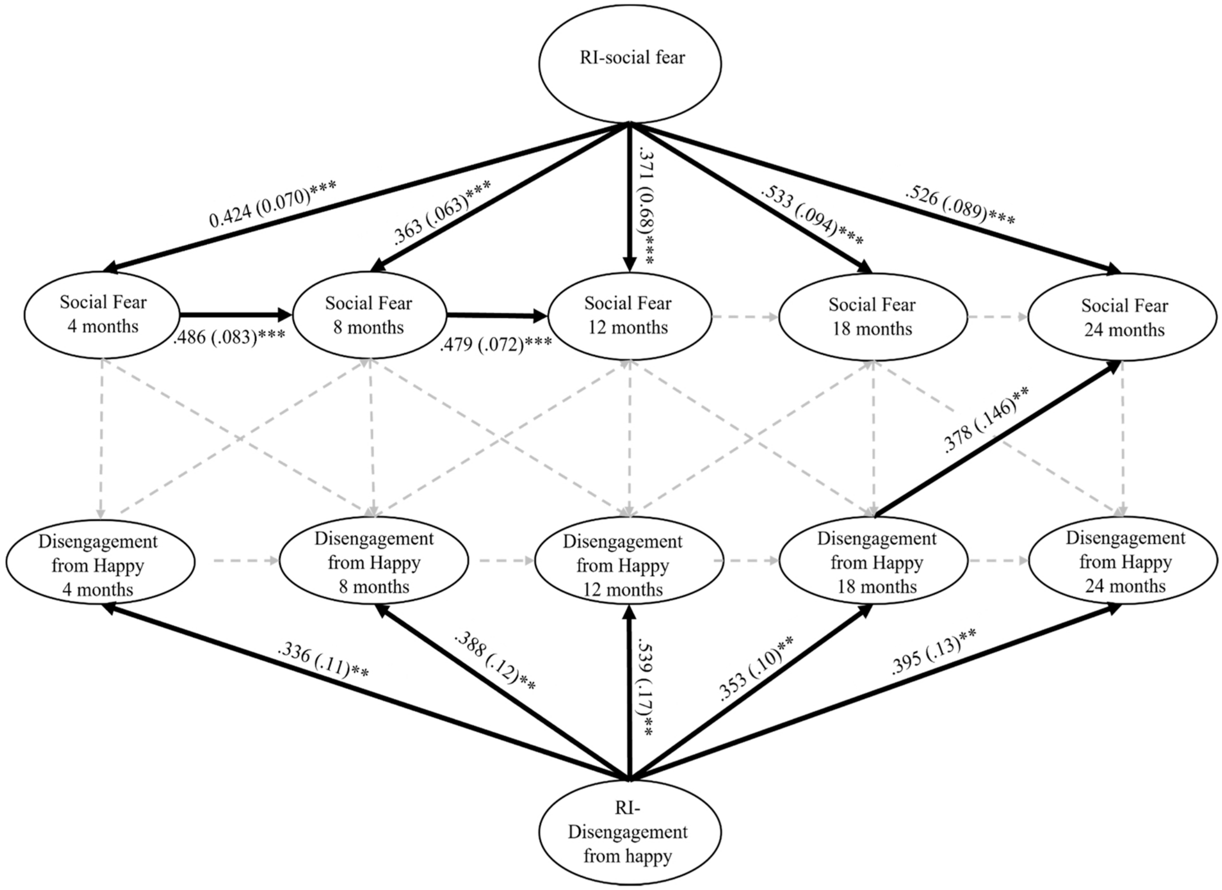


Fig. 8. Results from ri-clpm with social fear and disengagement from happy faces (model 6). Values given are standardized coefficients and standard errors in parentheses. Black solid lines indicate a significant relationship between variables and grey dashed lines indicate non-significant paths. Paths between random intercepts were not significant and omitted for visualization purposes (Note: * indicates $p < .05$, ** indicates $p < .01$., and *** indicates $p < .001$).

4. Discussion

4.1. General discussion

Here we examined developing relations between attention to emotional stimuli and social fear over the first two years of life. There were several important findings. First, we found a relatively high amount of stability in social fear over time, with more stability in earlier assessments (4–12 months) than in later assessments (18–24 months) across tasks. This was not the case for attention biases for emotional facial configurations, where there was little evidence of stability in patterns of attention to any emotion in either of our tasks. Taken together, these findings suggest that patterns of attention bias for emotions (including threat) are not stable, and likely still developing over the first two years of life, supporting Field and Lester's (2010) moderation and acquisition models, but not the integral bias model.

In terms of *rapid detection*, we found that less stability in latency to fixate happy facial configurations at 12 months was related to more stability in social fear at 18 months. We also found concurrent relations between stability in social fear and latency to detect angry faces at 12 months. Thus, while stability in patterns of first fixations to angry (negative) facial configurations was related to stability in social fear, instability in first fixations to happy (positive) emotions was related to more stability in social fear.

For *engagement*, we found evidence of unidirectional relations between social fear and engagement with positive and neutral facial configurations in the first year of life. Specifically, more stability in social fear at 4 months was related to more stability in engagement with happy facial configurations at 8 months. Similarly, more stability in social fear at 8 months was related to less stability in engagement with neutral faces at 12 months, suggesting that social fear is prospectively related to patterns of engagement with both happy and neutral facial configurations in the first year of life. Thus, the relation between stability in social fear and emotional valence was the opposite as it was with latency: here, more stability in social fear was related to more stability in engagement with positive emotions and less stability in engagement with neutral displays.

While relations between social fear and engagement with emotional stimuli emerged in the first year of life, relations between

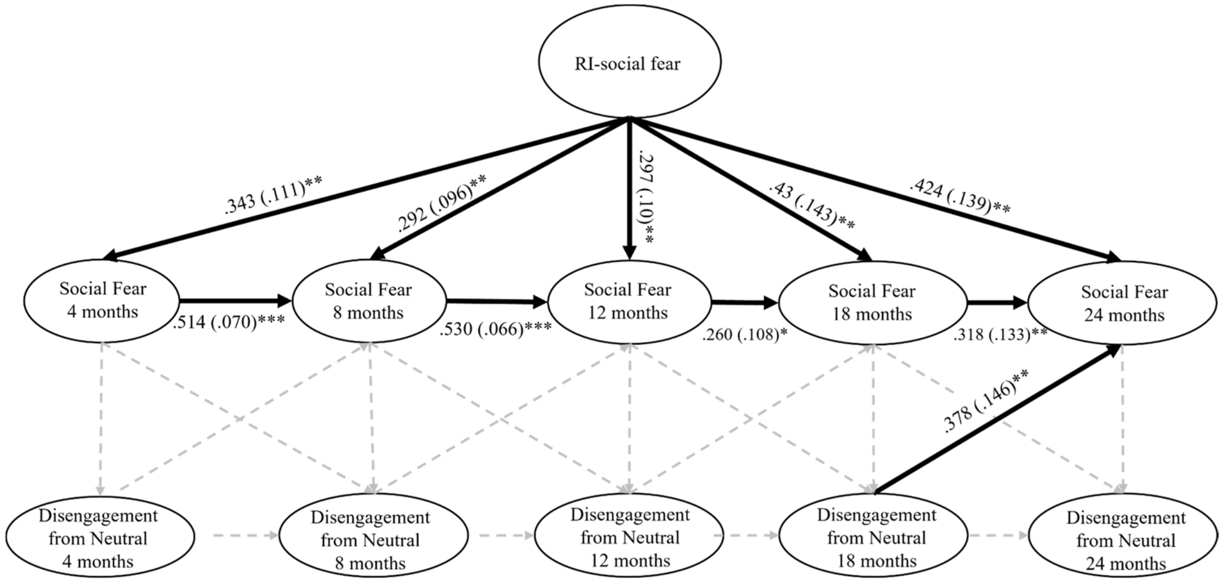


Fig. 9. Results from ri-clpm with social fear and disengagement from neutral facial configurations (model 7). Values given are standardized coefficients and standard errors in parentheses. Black solid lines indicate a significant relationship between variables and grey dashed lines indicate non-significant paths (Note: * indicates $p < .05$, ** indicates $p < .01$., and *** indicates $p < .001$).

social fear and *disengagement* from various emotional facial configurations did not emerge until the second year. Specifically, more stability in disengagement from both happy and neutral facial configurations at 18 months was related to more stability in social fear at 24 months. Further, infants who showed more stability in social fear at 12 months also showed more stability in their tendency to disengage or look away from angry facial configurations at 18 months, which in turn was related to more stability in social fear at 24 months. Here, stability in disengagement from all emotional stimuli was related to stability in social fear, especially for angry or threatening facial configurations where a more reciprocal relation unfolded over time.

Collectively, these findings indicate that infants with more stable patterns of disengagement from emotion facial configurations also showed more stable patterns of social fear over time. Previous research has suggested that rigidity in attention bias patterns is related to social anxiety (e.g., Morales et al., 2017b), thus these findings are much in line with previous research, demonstrating that rigidity in patterns of disengagement from emotional stimuli was related to more stability in social fear. This relationship was particularly pronounced for angry facial configurations, with reciprocal relations between looking away from threat and social fear developing between 12 and 24 months. Importantly, while we found reciprocal relations between social fear and disengagement from emotional facial configurations in the second year of life, we also found intermittent signs of concurrent and unidirectional relations between social fear, rapid detection, and engagement with emotional facial configurations in the first year of life.

It is possible that these developmental differences are due to the nature of the tasks. Indeed, rapid first fixations to and engagement with emotional stimuli could reflect more automatic, nonconscious processing, evident between 4 and 12 months, while looking away from these stimuli could reflect more deliberate, conscious processing that does not develop until 12–24 months—a time when infants begin to use emotional information to guide action (e.g., Mumme et al., 1996; Mumme & Fernald, 2003; Sorce et al., 1985; Tamis-LeMonda et al., 2008)). The implication is that more top-down attention—as opposed to bottom-up, automatic responding—to threatening facial configurations is most relevant to developing patterns of social fear. Further, it is worth noting that, similar to other recent work (Vallorani et al., 2021), patterns of attention bias in general and their relation to social fear were only emerging in the first two years of life and were not yet stable over time. Thus, one implication from this work is that intervention in the early infancy years—before potentially maladaptive patterns of attention bias become stable—could be an important avenue of exploration. Another is that more rigid patterns of attention bias to emotional stimuli—especially a bias to look away from threat—are prospectively and reciprocally related to more stable patterns of social fear over time.

4.2. Limitations and implications for future research

While this study is one of the first to test developmental models of attention bias to threat (Field & Lester, 2010) longitudinally in the first two years of life, it was not without limitations. First, we used a parent-report measure of social fear. Although this is not uncommon in the literature, it can provide a more biased account of social fear than a behavioral measure. Further, this metric was used here in infants as young as 4 months of age. Behaviorally, social fear is typically first observed in infants between the ages of 8–12 months (see LoBue & Adolph, 2019 for a review), so the findings between 4 and 8 months should be interpreted with caution. Future research incorporating both parent reports and behavioral measures of social fear might provide a more rigorous account of this behavioral outcome.

Further, we only measured the infants until the age of 2, when the interaction between attention biases and social fear seems to be emerging for the first time. Other studies have demonstrated such an interaction around age 5 when children begin school (LoBue & Pérez-Edgar, 2014; Pérez-Edgar et al., 2011) and throughout adolescence (Pérez-Edgar et al., 2010), but we still do not know how those interactions develop between toddlerhood and age 5. Not only are children likely to engage in more social interactions as they approach kindergarten, but their social circle also expands from primarily family members to include more peers during playdates or daycare as well. Thus, as children engage in more social interactions and learn more about how to use emotions to navigate those interactions, the relations between attention bias to threat and social fear might also change over time. Future research that extends our age range and bridges the gap between toddlers and school-aged children would be important to establish the link between social fear and later social anxiety symptomatology.

4.3. Final conclusions

Despite these limitations, this study is one of the first to examine the developing relations between attention to threat and social fear over the first two years of life. Further, we examined three components of the attention system—orienting, engagement, and disengagement—providing a more comprehensive account of the nature of attention biases and their development over time. Our findings suggest that characteristics of behaviorally inhibited temperament, namely social fear, begin to interact with attention biases to emotion in the very first year of life, and when combined with previous work, supports the moderation and acquisition models by Field and Lester (2010). More specifically, we found stability in social fear but not in attention to emotional stimuli over time. Further, there were concurrent and unidirectional relations between social fear, rapid detection, and engagement with emotional facial configurations in the first year of life. Most importantly, infants with more stable patterns of disengagement from emotional facial configurations in the second year of life—especially threatening configurations—were more stable in social fear over time, suggesting that stability in disengagement or avoidance of threat interacts with social fear over the course of development. Future research should build upon this work to examine how social fear and attention patterns continue to influence one another throughout early childhood, and how they may predict the development of anxiety symptoms later in life.

Declaration of Competing Interest

The authors declare no conflicts of interest.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.infbeh.2022.101750.

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