The impact of negative affect on attention patterns to threat across the first two years of life.

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Abstract

The current study examined the relations between individual differences in attention to emotion faces and temperamental negative affect across the first two years of life. Infant studies have noted a normative pattern of preferential attention to salient cues, particularly angry faces. A parallel literature suggests that elevated attention bias to threat is associated with anxiety, particularly if coupled with temperamental risk. Examining the emerging relations between attention to threat and temperamental negative affect may help distinguish normative from at-risk patterns of attention. Infants (*N*=145) ages 4 to 24 months (*Mean*=12.93 months, *SD*=5.57) completed an eye-tracking task modeled on the attention bias "dot-probe" task used with older children and adults. With age, infants spent greater time attending to emotion faces, particularly threat faces. All infants displayed slower latencies to fixate to incongruent versus congruent probes. Neither relation was moderated by temperament. Trial-by-trial analyses found that dwell time to the face was associated with latency to orient to subsequent probes, moderated by the infant's age and temperament. In young infants low in negative affect longer processing of angry faces was associated with faster subsequent fixation to probes; young infants high in negative affect displayed the opposite pattern at trend. Findings suggest that although age was directly associated with an emerging bias to threat, the *impact* of processing threat on subsequent orienting was associated with age and temperament. Early patterns of attention may shape how children respond to their environments, potentially via attention's gate-keeping role in framing a child's social world for processing.

The centrality of attention in development grows out of its role as a brain-based mechanism whose core function is to influence the operation of other mechanisms. Attention acts by selecting information for further processing, maintaining this focus as needed, and disengaging from the focus of attention when it no longer serves current goals (Posner & Rothbart, 2007). The earliest forms of exploration, learning, and self-regulation are rooted in the ability to disengage, shift gaze, and re-orient on a new focus of attention (Rothbart, Posner, & Rosicky, 1994). In this way initial attention may have a cascading effect on subsequent action selection and learning (Scerif, 2010), allowing infants to shape their experienced environments (Morales, Fu, & Pérez-Edgar, 2016; Pérez-Edgar, Taber-Thomas, Auday, & Morales, 2014) and their own socioemotional trajectories (Brooker et al., 2014) from the first days of life.

Two generally separate literatures have examined the development and impact of attention to threat. One line of research suggests that infants show a normative bias to attend to threat by the second half of the first year of life (Peltola, Leppanen, Maki, & Hietanen, 2009; Peltola, Leppanen, Vogel-Farley, Hietanen, & Nelson, 2009). Little is known regarding the developmental trajectory of these biases over time. The second line of research suggests that attention processes, specifically attention bias to threat, may play a causal role in the emergence of anxiety in adolescents and adults, particularly if individuals are at temperamental risk (Roy, Dennis, & Warner, 2015). However, little is known regarding how these relations first emerge. Thus, there is a current gap in our understanding of how early normative patterns may reflect later profiles marked by individual differences in socioemotional functioning.

The current study uses eye-tracking methods to examine patterns of attention to threat in a large cross-sectional sample of infants from four to twenty-four months of age. In doing so, we designed an infant version of the dot-probe task—the behavioral task most often presented in the child and adult literature (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). In addition, we characterize participants for levels of negative affect, a temperament trait that has been associated with attention to threat, behavioral inhibition, and the later emergence of anxiety (Fox & Pine, 2012). Our main goal is to characterize and track the initial, emerging relation between attention to threat and temperament traits that may shape divergent developmental trajectories.

Attention to Threat as a Normative Process

Orderly patterns of visual attention are evident within the first days of life. Initially, attention may be exogenously driven by processing and learning biases that are fairly normative and governed by subcortical neural networks (Leppänen & Nelson, 2006, 2009). However, over time, endogenous attention processes emerge and begin to dominate how, when, and where the infant deploys his growing, but still limited, attentional resources. For example, a recent study (Kwon, Setoodehnia, Baek, Luck, & Oakes, 2016) found that when faces are presented in a complex array of objects, 4-month-olds attend to the most perceptually salient stimulus, while 6- and 8-month-olds preferentially attend to faces, regardless of perceptual characteristics. It is at this point that clear individual differences may begin to have a broad and perhaps lasting impact on how individuals engage with and perceive their social environments.

Emotionally salient objects in the environment preferentially capture attention early on, often due to perceptual markers, such as shape and contrast (LoBue, Rakison, & DeLoache, 2010). In the competition for limited attentional resources, infants prioritize objects that decrease danger and increase reward (Peltola, Leppanen, Palokangas, & Hietanen, 2008), and no other object is as closely tied to survival, punishment, and reward as the human face (Hoehl & Striano, 2010). Due to the coupling of perceptual cues, rewarding daily events (e.g., feeding), and long hours of exposure, infants quickly begin to show preferential looking to human faces (Leppänen & Nelson, 2009). This preference is magnified when the face also conveys an emotional threat signal.

For example, a series of studies (Peltola, Hietanen, Forssman, & Leppänen, 2013; Peltola, Leppanen, Maki, et al., 2009; Peltola et al., 2008) has found that within the second half of the first year of life, infants are less likely to disengage from negative faces relative to happy and neutral faces. This may be due to infants' neurally-driven "sticky fixation" to attended stimuli (Hood & Atkinson, 1993), working in tandem with a normative bias to preferentially attend to stimulus valence (DeLoache & LoBue, 2009; LoBue & DeLoache, 2010; LoBue et al., 2010). As another example, the presence of an affective face will modulate the early-emerging eye-blink startle by 5 months of age, such that angry faces potentiate the startle response, which is in turn attenuated by happy faces (Balaban, 1995). Perceptual cues may initially capture infants' attention, setting the stage for later conceptual learning regarding the meaning conveyed by emotion faces (Quinn, 2011). This learning has down-stream consequences as patterns of attention to emotion in infancy are associated with patterns of attachment as toddlers (Peltola, Forssman, Puura, IJzendoorn, & Leppänen, 2015).

Temperament-linked Differences in Threat Processing

At the same time, individual differences in temperament may shape the type of information infants seek out, endogenously modulating their level of exposure to social stimuli. Much of the infant attention literature has focused on normative patterns of behavior, noting the early emergence of attention bias to threat and potential links to underlying cognitive, perceptual, and socioemotional mechanisms (Leppänen & Nelson, 2009; LoBue, Matthews, Harvey, & Stark, 2014). The data indicate that attention to threat is early appearing, widespread, evident at the neural level, and independent of a fear response (LoBue, 2013; Ravicz, Perdue, Westerlund, Vanderwert, & Nelson, 2015). Nonetheless, studies examining the association between attention to threat and the emergence of socioemotional maladaptation or anxiety have predominantly focused on child and adult clinical populations (Bar-Haim et al., 2007; Brown et al., 2014).

Recent meta-analyses (Dudeney, Sharpe, & Hunt, 2015) and reviews (Roy et al., 2015) of attention bias to threat in anxious children finds that there is equivocal support for the presence and direction of the attention bias. There is clear evidence that temperament impacts socioemotional development throughout childhood beginning in infancy. The role of attention, however, has not been extensively examined from the first years of life. A broad literature notes that infants with high levels of negative affect in infancy are at increased risk for behavioral inhibition or dysregulated fear by early childhood (Buss, 2011; Fox, Henderson, Rubin, Calkins, & Schmidt, 2001). Children high in behavioral inhibition and dysregulated fear are, in turn, at increased risk for social withdrawal and social anxiety by early childhood and adolescence (Buss & Kiel, 2013; Chronis-Tuscano et al., 2009).

Initial work suggests that attention mechanisms may act as a developmental tether, increasing the likelihood that children remain on early developmental trajectories and resist the normal ameliorative or "smoothing away" processes that typically diminish early risk (Pérez-Edgar et al., 2014). As a result, infants with low levels of sustained attention (Pérez-Edgar et al., 2010) or executive attention (Sheese, Rothbart, Posner, White, & Fraundorf, 2008) to non-social stimuli show increased levels of social withdrawal over the course of early childhood. The inability to disengage from a distressing stimulus may "force" processing resources to remain focused on the stimulus, thus increasing negative affect or anxiety (Fox, Hane, & Pine, 2007). Individual differences in temperament, particularly when coupled with variations in attention control, may also make infants more attune to environmental variations, leading to differential susceptibility (for both good and ill) to life events (Belsky & Pluess, 2009).

While studies have examined the relation between temperament and attention to threat in childhood, there is less data concerning this relation early in infancy. A small longitudinal study tested infants at 12, 18, 24 and 36 months (Nakagawa & Sukigara, 2013), noting a main effect of emotion face, such that infants were less likely to disengage from fearful faces than happy or neutral faces. This bias pattern was stable across time in the sample. However, they only found a relation between maternal report of negative affect and attention to threat at a single time point—12 months. The authors suggest that the emergence of regulatory processes, such as effortful control, may have modulated the temperament-attention relation. Previous work (Martinos, Matheson, & de Haan, 2012) found no changes over time in the relation between temperament (negative affect and regulation) and electrophysiological markers of attention to threat and happy faces. This study included infants from 3 months to 13 months, although most clustered at 7 months. It is not clear if a similar pattern would emerge in a sample with a wider age range using eye-tracking measures of attention. Finally, a recent study finds that while maternal anxiety was associated with infant attention bias in an eye-tracking disengagement task, temperamental negative affect was not (Morales et al., in press).

The Current Questions of Interest

The currently available data lead to a core set of questions concerning how the relation between attention to threat, negative affect, and anxiety/social withdrawal may emerge over time. Three potential developmental models have been suggested. The integral bias model (Field & Lester, 2010) suggests that individual factors (e.g., temperament) determine the extent of any bias and bias should be evident across the lifespan, assuming that the task is developmentally appropriate. As such, infants with early signs of negative affect would already show a more pronounced bias to threat relative to infants without this temperamental profile. Much of the current clinical literature makes this *implicit* assumption. The moderation model (Field & Lester, 2010) suggests that development moderates the expression of an existing bias to threat, such that under certain circumstances (e.g., in children with extreme temperament) the initial normative bias may be linked to the later emergence of elevated fear and social withdrawal (LoBue, 2013; LoBue & DeLoache, 2008; Todd, Cunningham, Anderson, & Thompson, 2012). In contrast, normative biases will decrease over time for typically developing children. Finally, the acquisition model suggests that developmental experiences shape the acquisition of an attention bias gradually over time (Field & Lester, 2010), either in tandem or subsequent to the emergence of fear and anxiety. For example, Kindt (Kindt, Bierman, & Brosschot, 1997; Kindt & Brosschot, 1999) has found that attention bias to spiders increases with age cross-sectionally for phobic, but not control, children (however, see Morren, Kindt, van den Hout, & van Kasteren, 2003). To date, the available data cannot definitively address the three models.

The current study is an initial examination of attention bias and negative affect in the first two years of life, focusing on mechanisms thought to shape broad patterns of socioemotional behavior in older children and adults. Our infant eye-tracking task is modeled directly on the dot-probe task most commonly used to assess attention bias in older individuals (Bar-Haim et al., 2007). In this task, individuals briefly see two competing stimuli (one neutral and one threatening) and then respond to a probe that appears in the same location as one of the stimuli. An attention bias towards emotional stimuli is present when participants preferentially attend to emotional cues, marked by decreased RTs to probes replacing the threatening cues compared to the neutral cues, presuming that faster responses indicate that attention was already at that location. Bias is reflected in a simple difference score comparing RTs across cueing conditions.

As a practical matter, eye-tracking measures are needed to capture attention patterns, as infants cannot produce the needed overt responses central to the behavioral task. Eye-tracking measures can also provide unique data concerning task performance that is obscured in RT measures. RT studies assume that patterns of vigilance or avoidance are driven by core attention preferences. However, it is likely that multiple perceptual, cognitive, and motoric processes are also at play in the window between face presentation and probe response. Eye-tracking data may help partially disentangle these overlapping processes by removing the need for an overt motor response and providing more fine-grain temporal information regarding visual attention. Eye-tracking may also help verify that a participant is (or is not) visually attending to the stimuli presumed to drive attention bias. Recent work examining eye-tracking in children ages nine- to forty-eight months in a dot-probe task suggests that the task shows positive internal reliability (Burris, Barry-Anwar, & Rivera, in press), particularly when compared to recent concerns regarding the behavioral RT version of the task (Rodebaugh et al., 2016)

We rely on our new, infant-appropriate dot-probe task (the 'Baby Dot-Probe') to address a number of specific questions. First, can infants reliably complete an eye-tracking version of the standard dot-probe task, patterned on the protocol normally used with children and adults? Second, do individual differences in temperamental negative affect and age impact infants' attention to emotion faces cues in the task? Third, can we use eye-tracking data to detect the attention mechanisms (i.e., disengagement from face to cue) that are thought to underlie the standard RT version of the task? Fourth, do face processing measures (dwell time) account for individual differences in response to the probes (fixation latency)?

The behavioral RT literature assumes that responses to probes are affected by attentional capture by the preceding emotion faces, such that individuals who attend to a location (e.g., an angry face) should be faster to then respond to a congruent probe and slower to respond to the incongruent probe. If infants in the current study match this previous pattern, we expect visual attention to an emotion face will lead to increased latencies to fixate to probes in the opposite spatial location. In addition, increased dwell time to faces, particularly if angry, will be associated with increased latencies to fixate to probes that follow in the opposite spatial location. With respect to temperament, it may be that negative affect impacts exogenously-driven attention. Thus, the relation between dwell time and latency may hold for all infants, but it is simply that infants high in negative affect dwell longer to threat faces, thus triggering the latency response. Alternately, it may be that attention to threat faces differentially impacts subsequent attention, such that the dwell-time latency coupling will only be found in infants high in negative affect. If a temperament-attention link is noted, the relation may be evident throughout the observed age window (integral bias model) or it may emerge over the course of infancy into toddlerhood (moderation and acquisition models). Happy-Neutral trials were included in the study in order to probe the specificity of these relations to threat cues.

This is the first study to empirically examine the form and function of attention bias to threat incorporating individual differences in temperament in the first years of life in order to directly assess early relations often implicit in the developmental and clinical literatures. Thus, this study aims to elucidate core processes in social-emotional development thought to underlie patterns of behavior and functioning examined later in life. In doing so, we provide an empirical and methodological foundation for subsequent large-scale, longitudinal studies on the developmental relation between attention bias to threat and anxiety.

Method

Participants

Participants in the current analyses were part of a larger study (N=255, 143 males, $Mean_{age}$=11.37 months; SD_{age}=5.74, $Range_{age}$=4.00 to 24.90 months) involving multiple tasks examining the early temperament-attention link. We present here data from the dot-probe task component of the protocol. Participants were recruited via mailings sent to parents identified in a university-based database of families interested in research, as well as community advertisement. The initial sample was predominantly Caucasian (87.3%), reflecting the surrounding semi-rural community. The remaining 12.7% of families self-identified as Asian-American, African-American, Native-American or Hispanic. In all but ten families, the mother completed the questionnaire measures noted below. All families reported that English was spoken at home, while 23 infants were also exposed to a second language. All children, except two, were living with a biological parent. Infants were born within three weeks of their due date, had no major birth complications, and had adequate birth weight ($Mean_{weight}$=7.66 lbs, SD_{weight}=1.13). Families reported that infants were meeting motor milestones (rolling over, crawling, and walking) within normal developmental windows. Age of milestones was not associated with task variables, p's>.24.

We did not have a direct comparison in the literature for calculating a projected sample size for the study, due to our novel examination of interaction effects and our use of trial-by-trial mixed effects models. However, we were able to derive effect size estimates from recent papers examining main-effects and two-way interactions in infant eye-tracking studies of attention to threat (LoBue, Buss, Taber-Thomas, & Pérez-Edgar, 2017; Morales et al., in press). These studies found medium effect sizes (d's between 0.37 and 0.42) for the comparable analyses. A total sample size of 77 to 96 is projected to detect effects at α=0.05, two-tailed, at a power of 0.95 for effect sizes within the range of the measures reviewed (G*Power 3.1.9.2) (Faul, Erdfelder, Lang, & Buchner, 2007). Our final sample size of 145 should be adequate to find any evident relations for the standard classical significance tests.

The University Institutional Review Board approved all procedures. Families provided written consent and were compensated for their participation.

Infant Negative Affect

Individual differences in early childhood temperament were assessed via parental report of behavior using one of two standardized questionnaires.

<u>Infant Behavior Questionnaire-Revised (IBQ-R).</u> The IBQ-R (Gartstein & Rothbart, 2003) is a 191-item rating form asking parents to rate the frequency of specific infant behaviors as they occurred in the previous week. Parents of 4- to 12-month-old infants (N=142, 78 males, $Mean_{age}$=7.26 months, SD_{age}=2.48) rated the frequency of behaviors using a seven-point scale with an eighth option for ‘Does not apply’. Scaled scores were derived by taking the mean ratings on all items in the particular scale, omitting the items marked as ‘Does not apply’. Of particular interest in this study was the ‘Negative Affect’ factor, made up of the sadness, distress to limitations, fear, and reactivity/recovery subscales ($Mean_{IBQ\text{-}R}$=3.63, $SD_{IBQ\text{-}R}$=0.47, Cronbach’s α=.81).

<u>Toddler Behavior Assessment Questionnaire (TBAQ).</u> For infants between 12 and 24 months (N=105, 57 males, $Mean_{age}$=16.96 months, SD_{age}=4.06), parental reports of temperament were gathered using the TBAQ (Goldsmith, 1996). The TBAQ is a 120-item rating form in which parents are asked to rate the frequency of specific behaviors as they occurred in the past month. The TBAQ is modeled after the IBQ and uses a similar response format—a seven-point Likert

scale with an eighth option for ‘Does not apply’. Scaled scores are created by taking the mean of items for a particular scale, omitting all items answered with ‘Does not apply’. Of particular interest in this study was a ‘Negative Affect’ factor created from the TBAQ sadness, anger, social fear, and object fear subscales ($Mean_{TBAQ}$=3.23, SD_{TBAQ}=0.58, Cronbach’s α=.82).

Full-Sample Negative Affect Score. Infants characterized by the IBQ-R and TBAQ did not differ in sex, birth-weight, or other demographics (p’s>0.29), except for the presence or absence of age-linked motor milestones. In order to carry out the analyses below with the full sample, individual scores from each questionnaire were standardized ($Range_{IBQ\text{-}R}$=-2.25 to 3.24; $Range_{TBAQ}$=-2.03 to 3.10) and combined into a single Negative Affect measure ($Mean_{NA}$=0.00, SD_{NA}=1.00). Data were available from 247 infants.

For the overall sample, there was a marginal relation between Negative Affect and Age, $r(244)=0.10$, $p=0.10$. The relation approached significance when assessed among the older infants, $r(104)=0.18$, $p=0.06$. Negative Affect significantly increased with Age for younger infants, $r(140)=0.22$, $p=0.01$. The relation disappeared, $p=0.51$, when controlling for child mobility. This is in line with the literature noting a spike in negative affect in the second half of the first year of life with the advent of locomotion and accompanying increases in parental control (Uchiyama et al., 2008). There were no Sex-linked differences in Negative Affect for the full sample, $t(243)=-0.59$, $p=0.55$, $d=0.08$, or separately for the older and younger infants, p’s>0.29.

Infant Dot-Probe Task

The task consisted of 30 experimental trials. Each trial began with a central fixation (a clip from a children’s movie), which was presented until the infant fixated for at least 100ms (Figure 1). The fixation stimulus was then followed by one of three types of face pairs taken from the

NimStim face stimulus set (Tottenham et al., 2009): Angry-Neutral (6 congruent trials, 6 incongruent trials), Happy-Neutral (6 congruent trials, 6 incongruent trials), and Neutral-Neutral (6 trials). There were 6 faces used (half male), all presented once in each face-pair type. The face pictures were each 14.0 cm X 19.0 cm and were presented side-by-side, with a distance of 26.5 cm between their centers. As recommended (Oakes, 2012), trial initiation was triggered by infant fixation rather than pre-determined presentation timings.

Although much of the dot-probe literature has focused on 500 ms face-presentation times (Bar-Haim et al., 2007; Burris et al., in press; Van Bockstaele et al., 2014), many studies have shortened or lengthened this time in order to capture variations in attention bias patterns (Mogg, Bradley, De Bono, & Painter, 1997). Given the infant sample in the current study, faces were presented for 1000 ms, providing sufficient time to capture eye-gaze patterns for even the youngest participants. Faces were then removed and immediately replaced by a probe (a black asterisk centered on a white screen), which remained on screen for 500 ms. Trials were originally designated as congruent if the probe appeared in the same location as the affective face (i.e., Angry or Happy) and incongruent if appearing in the location of the Neutral face. Thus, we counterbalanced task-defined congruent and incongruent trials. Face sex and probe location (right/left) were also counterbalanced throughout. The inter-trial interval was 1000 ms. Task presentation was controlled by Experiment Center (SensoMotoric Instruments, Teltow, Germany).

Eye-Tracking Procedure

The eye-tracking data were obtained using a RED-m Eye Tracking System (SensoMotoric Instruments) and an integrated 22-inch presentation monitor (8.5 cm by 6.3 cm screen). Infants were seated 60 cm from the monitor on either an adjustable highchair, or their parent’s lap, such that their eye gaze was centered on the screen. The eye-tracker monitor has cameras embedded that record the reflection of an infrared light source on the cornea relative to the pupil from both eyes. The average accuracy of this eye-tracking system is in the range of 0.5 to 1°, which approximates to a 0.5 to 1 cm area on the screen with a viewing distance of 60 cm. The testing procedure began with a 5-point calibration and four-point validation procedure using an animated multicolored circle. Testing continued until all 30 trials had been presented, or the infant's attention could no longer be maintained. Gaze information was sampled at 60 Hz and collected by Experiment Center.

Areas of interests (AOI) encircling and including the entire face and probe display areas were created using BeGaze (SensoMotoric Instruments). Subsequent analyses were based on gaze data within the specified face or probe AOIs. Fixations, defined as gaze maintained for at least 80 milliseconds within a 100-pixel maximum dispersion, were extracted with BeGaze. Fixation locations and durations within face and probe AOIs on each trial were calculated with in-house Python (Python Software Foundation, http://www.python.org/) and MATLAB (The MathWorks, Inc., Natick, Massachusetts, USA) scripts. Trial data were subsequently extracted and processed using SPSS v22 (Chicago, IL).

Eye-tracking Data Processing

Data processing procedures were set to improve the data available for subsequent analyses. This is in line with the infant literature's (Leppänen, 2016; Oakes, 2012) concern for designing tasks that are amenable for infant use, provide a rich, yet reliable, data set, and balance concerns regarding Type I and Type II error. As such, we had a multi-step process that spanned from data collection to data processing, excluding infants or data that were likely to introduce excessive noise.

First, if infants were overly distressed or deemed unable to attend to the procedures, we did not attempt this specific task. Of the 255 infants enrolled in the larger study, 237 attempted the task. Then, if the infant was unable to calibrate at the start of the task or stopped attending during the first-half of the task, he/she was designated as not having completed the task (N=63). If an infant made it past the half-way point of the task (i.e., 15 trials), we continued the task to the end and infants were designated as having completed the task.

We then assessed the quality of the collected data post-visit. We first examined calibration data, specifically the average deviation of the infant's eye gaze relative to the location of the 5 calibration points. If the deviation of the coordinates in the X or Y direction was greater than four degrees, the child was excluded from further processing (N=29). This is in line with reviews suggesting that initial calibration is crucial to providing robust and reliable data (Morgante, Zolfaghari, & Johnson, 2012).

Once an infant met each criterion, all data provided by the infant were deemed available for analyses. As such, eye-tracking data were available from 145 infants (56.9%). Although studies vary widely on inclusion/exclusion criteria, the final yield is normative for laboratory studies in this age range (Stets, Stahl, & Reid, 2012).

Statistical Analyses

Data extraction focused on measures of attention and emotion processing: (1) dwell time on each face, and (2) latency to fixate to the probe, which paralleled the RT button press measure used in the behavioral dot-probe literature. In order to test the affect-attention models outlined by Field and Lester (2010), Negative Affect score and Age at testing were included in the analyses. Sex was initially included based on previous data suggesting that the interaction between temperament and emotion processing may differ in boys and girls (Fox, Snidman, Haas, Degnan, & Kagan, 2015; Henderson, Fox, & Rubin, 2001; Pérez-Edgar, Schmidt, Henderson, Schulkin, & Fox, 2008) and parallel studies suggesting sex-linked differences in fear acquisition (Rakison, 2009). However, we noted no systematic Sex-linked findings. As such, the variable was subsequently removed from analyses for parsimony.

Initial analyses focused on characterizing the infants' pattern of performance on the task, looking to see if the task was suitable for use in a young sample. This included the pattern of missing data, as a function of Age and Negative Affect, and the relations between core measures from the task.

Subsequent analyses then turned to our core empirical questions and examined the relation between early temperament and emotion-face processing, incorporating individual differences in Negative Affect and Age.[1]

Attention to Emotion Faces

We examined patterns of attention to emotion faces as a function of Negative Affect and Age. These analyses used mean Dwell Time averaged across task-defined trials to the emotion faces, using neutral faces to control for general visual attention patterns. We used a mixed measures ANCOVA incorporating a 2 (Face Emotion: Angry vs. Happy) by Age (continuous) by Negative Affect (continuous) model, covaried by Neutral faces (continuous).

Impact of Attention Location on Probe Fixation

The standard RT form of the dot-probe task is predicated on the notion that attention location impacts the speed of subsequent button presses, particularly when the participant must shift attention to a new probe location. Thus, the trials are designated as congruent or incongruent

[1] Although the infants characterized by the IBQ and TBAQ were comparable across our measures (except for age) we looked to see if there were questionnaire-associated effects on our analyses by running the core analyses separately for each age group. In general, the findings were intact although they toggled above and below the standard significance threshold due to the restricted age ranges and relatively diminished power.

based on *a priori* expectations of where attention will be localized. However, eye-tracking technology allows researchers to designate congruent and incongruent by the actual location of visual fixation, rather than trial design. As such, the second set of analyses defined congruent and incongruent based on a trial-by-trial characterization of eye-gaze location creating gaze-defined congruent and incongruent trials.

For example, a gaze-defined trial was only considered angry incongruent if the infant visually attended to the angry face just prior to the appearance of the probe in the opposite location. That is, even if the trial had *a priori* been task-defined as an incongruent trial due to programming the angry face and probe to be in different locations, this trial was re-designated as gaze-defined congruent if the infant was in reality fixated on the neutral face location immediately prior to the probe presentation.

This new categorization was carried out for each trial, for each infant, yielding 9 different gaze-defined conditions (angry congruent, angry incongruent, happy congruent, happy incongruent, neutral, neutral congruent during an angry trial, neutral incongruent during an angry trial, neutral congruent during a happy trial, and neutral incongruent during a happy trial). Our analyses focused on the angry incongruent and happy incongruent trials, as these trials assure the infant was attending to the emotion face and required the infant to disengage and locate the probe. For the trial-by-trial analyses, we did not focus on latency in congruent trials (eye-gaze in the location of the eventual probe) as it is difficult to characterize what processes lead to latency scores since there was no need to disengage and shift to fixation.

For the trial-by-trial mixed effects models, we noted, and controlled for, the time in trial of the infant’s final fixation to the face prior to the probe presentation.

Impact of Face Processing on Probe Fixation

The final analysis evaluated the impact of attending to emotion faces on subsequent probe fixation. This analysis built directly on the trial-by-trial probe fixation analysis. Again focusing on gaze-defined incongruent trials, we looked to see if Dwell Time to the emotion face was associated with how quickly they fixated to incongruent probes. We further looked to see if this pattern varied by Negative Affect and Age. This analysis began by examining an omnibus interaction between Face fixated (Angry vs. Happy), Dwell Time, Negative Affect, and Age to predict the Latency to attend to the probe during incongruent trials using a trial-by-trial mixed effects model.

Results

Individual Difference Variables of Interest—Age, Negative Affect, and Sex

As noted above, 145 infants provided data for analyses. However, not all infants provided data in every condition. For example, if an infant never fixated on a Neutral face in an Angry-Neutral trial, this would result in an empty cell for Dwell Time. As such, the *N* varied across specific analyses. Means and correlations for the task-defined core measures are presented in Tables 1 and 2.

Of the infants who attempted the task, those providing data were older ($Mean_{age}$=12.93 months, SD_{age}=5.57, $Range_{age}$=4.00 to 24.30 months) than the infants that did not complete the task ($Mean_{age}$=9.33 months, SD_{age}=5.32, $Range_{age}$=4.00 to 24.90 months), $t(253)=5.20$, $p<0.001$, $d=0.65$.

Infants who completed the task were no different in Negative Affect versus infants who did not complete the task ($\text{Mean}_{\text{NA-Included}}$=0.08, $SD_{\text{NA-Included}}$=1.01 vs. $Mean_{\text{NA-Excluded}}$=-0.12, $SD_{\text{NA-Excluded}}$=0.97), $t(242)=1.59$, $p=0.11$, $d=0.20$.

There were no Sex-linked differences in the infants' ability to complete the task,

$X^2(255)=0.22$, $p=0.64$. In addition, there were no differences between male and female infants in other demographic variables, p's>0.30, or task performance, t's<1.23, p's>0.21.

Attention to Emotion Faces

In our ANCOVA for Dwell Time, we found an interaction between Face Emotion and Age, $F(1,124)=4.00$, $p=0.048$, $d=0.36$ (Figure 2). In probing the interaction, the partial correlations between Age and Dwell Time was significant for Angry faces, $r(125)=0.18$, $p=0.04$, but not Happy faces, $r(125)=-0.03$, $p=0.74$, with $Z=1.66$, $p=0.09$, two-tailed, when comparing the correlations.

There were no significant effects involving Negative Affect, F's<0.140, p's>0.71, d's<0.07.

Impact of Attention Location on Probe Fixation

In order to validate the core assumption of the dot probe task, namely that behavioral difference scores reflect patterns of attending to and disengaging from threat, we used a mixed effects model to examine latency to fixate to gaze-defined incongruent probe based on a trial-by-trial characterization of visual attention location. This model revealed that there was a significant effect of visual attention location on Latency, $b=110.63$, $t(350)=5.26$, $p<0.001$ (Figure 3). As expected, we found longer latencies for incongruent trials. This effect did not vary as a function of Face Emotion (i.e., Trial type by Emotion interaction), $b=39.41$, $t(350)=1.29$, $p=.20$. In addition, the main effect of Emotion on Latency was not significant, $b=-16.61$, $t(350)=-1.00$, $p=.32$.

Impact of Face Processing on Probe Fixation

The mixed effects model (based on 124 observations/trials) then examined the latency to attend to the probe during gaze-defined incongruent trials taking Dwell Time into account. We found a four-way interaction between Face Emotion (Angry vs. Happy), Dwell Time, Negative

Affect, and Age, b=-100.64, $t(49)$=-2.67, p=0.01. This interaction was probed by conducting separate mixed effects models on trials with fixations to Happy and Angry faces. These analyses (based on 56 observations/trials) revealed a significant three-way interaction (Dwell Time x Negative Affect x Age) for Angry faces, b=-75.30, $t(11)$=-2.43, p=0.03, while the interaction was not significant for Happy faces, b=27.84, $t(15)$=1.25, p=0.23.

The three-way interaction for Angry faces was further probed by examining the relation between Dwell Time and Latency at different levels of Negative Affect (+/-1 *SD*) for young and old infants (+/-1 *SD*). The effect of Negative Affect was evident only for young infants (Figure 4). There was a negative relation between Dwell Time to Angry faces and Latency to fixate to the probe for infants low in Negative Affect were faster to fixate to the probe after attending to Angry faces (b=-133.77, p=0.05). For high Negative Affect infants, the relation between Dwell Time was positive but not significant (b=111.94, p=0.19).

Discussion

The current study is the first to systematically assess the emergence of attention to salient emotional stimuli across the first two years of life while also incorporating individual differences in temperament. Previously, such an investigation was not possible due to methodological limitations in assessing attention biases in infancy. To address this issue, we employed an infant version of the classic dot-probe task central to the older child and adult literature, making it possible to examine potential patterns of bias in infants with methodological equivalency for the very first time. Using this new task, we probed untested presumptions regarding (1) the underlying visual attention mechanisms of the dot-probe task, (2) early biases to salient stimuli, and (3) the potential relation of temperament to early attention biases. Our results have important implications for all three issues.

First, we found that our new Baby Dot-Probe task was effective in measuring attentional biases in infants. This is in line with recent work using a variant of this task with an overlapping age range (Burris et al., in press). Further, using a novel trial-level analysis with eye-tracking, we were able to explicitly confirm the long-held assumption that attention location impacts the speed of subsequent fixations, particularly when a participant must shift attention to a new probe location. Second, we found evidence of early attentional biases for emotional stimuli, demonstrating that with age, infants spent greater time attending to emotional faces, particularly threatening faces. Finally, we found that young infants low in negative affect had shorter latencies to orient to the probe when attending longer to angry faces. Among young infants high in negative affect attending longer to angry faces was associated with (non-significantly) longer latencies to the subsequent probes. This pattern suggests that while age is associated with an emerging bias to threat, the *impact* of processing threat on subsequent orienting is shaped by both age and individual differences in temperament. Together, this important work opens the door, both conceptually and methodologically, to future research on the developmental relations between attentional biases for threat and the emergence of anxiety.

Attention mechanisms play a central role in development. Broadly, attention increases the probability of learning by focusing cognitive processes on a target, triggering psychophysiological orienting, and promoting coordinated neural activity (Colombo & Salley, 2015; Petersen & Posner, 2012). The initial attention state of alertness or readiness is evident early on postnatally and develops rapidly, soon joined by selective attention processes in the second half of the first year of life (Leppänen, 2016). The same attention processes that subserve core cognitive mechanisms, such as language learning, are also at play as infants attend to and derive meaning from their social environments.

Within the larger literature, the current study acts as a bridge between two related but often disparate literatures. A strong line of studies has examined the emergence of differential attention to, and processing of, emotion stimuli, particularly as linked to threat processing (Peltola et al., 2015; Peltola et al., 2013; Peltola, Leppanen, Maki, et al., 2009; Peltola et al., 2008; Peltola, Leppanen, Vogel-Farley, et al., 2009). This literature has focused almost exclusively on normative changes over time (but see Forssman et al., 2014; Morales et al., in press; Peltola et al., 2015; Ravicz et al., 2015). In parallel, the anxiety literature has examined individual differences in threat processing as a putative causal mechanism for the emergence of social maladjustment and disorder (Dudeney et al., 2015; Pergamin-Hight, Naim, Bakermans-Kranenburg, van IJzendoorn, & Bar-Haim, 2015). However, this work has focused almost exclusively on adults and young children. Thus, a developmental perspective examining how and when attention mechanisms may become linked to anxiety, negative affect, and social behavior/anxiety is missing (Morales et al., 2016).

Here we examined whether we could detect early emerging individual differences in the processing of threat expressions linked to dispositional differences in the expression of negative affect over the first two years of life. While we cannot examine patterns of social behavior/anxiety in this young age range, we can provide additional information regarding the earliest risk factors for these developmental outcomes. In doing so, we chose core components of both lines of research in order to aid interpretation of the emerging data. The larger sample size also allowed us to explore more complex questions than previously available, incorporating multiple potential contributors centered on temperament, sex, and age.

In the current data, dwell time to the presented faces increased with age. This pattern was most pronounced, both in zero-order correlations and the ANCOVA model, for angry faces. A general age-related increase in dwell time across all faces may simply reflect an increase in general attention control and processing mechanisms, which would support longer task engagement. Increases in dwell time would then simply follow as a secondary consequence of a larger developmental trend.

However, we found that the relation was strongest for angry faces, suggesting that with time infants may preferentially attend to these stimuli. This is in line with the argument that infants become more motivated to derive social information from faces (Oakes & Ellis, 2013), beginning in the second half of the first year of life (Kwon et al., 2016). Angry faces may be more salient than happy faces in this regard, reflecting the normative attention bias to threat evident in the infant literature (LoBue, 2009; LoBue & DeLoache, 2010).

Leveraging the temporal specificity of eye-tracking, we then examined if disengaging from the location of visual attention does indeed drive the bias effect seen in traditional reaction time studies. We found that relative to gaze-defined congruent trials, there is a latency cost to disengaging visual attention and fixating on a new probe location in gaze-defined incongruent trials. The effect was not shaped by face emotion or age, suggesting that this pattern reflects a basic perceptual mechanism that may be evident in the first months of life (Colombo, 2001)

The final analysis built on this mechanistic trial-by-trial analysis to explore if, beyond the simple location of visual attention, the time spent processing the presented stimuli impacts subsequent disengagement. Previous work using traditional means across conditions did not find a relation between dwell time (to 500 ms face presentation) and a bias score (incongruent minus congruent) calculated from fixation latencies (Burris et al., in press). In contrast, our within-trial analysis found an interaction between age, dwell time to angry faces, and negative affect in predicting latency to probes. With increases in Dwell Time to Angry faces, young infants low in

Negative Affect were faster to fixate to the probe after attending to Angry faces while young high Negative Affect infants did not show this pattern. Again, this finding was evident when infants had to disengage from an angry face and orient to the new probe location. There were no significant effects when infants were presented with happy faces or among older infants. One possibility consistent with past studies showing an association between negative affect and avoidance motivation (Hane, Fox, Henderson, & Marshall, 2008) is that young infants high in negative affect may be primed for avoidance (leading to slower subsequent orienting) when processing a threat-related stimulus, whereas young infants low in negative affect may be primed for approach (leading to faster subsequent orienting).

Although there are some indications of early sex-differences in threat-cue processing (Rakison, 2009), the infant literature suggests that the effect of sex in attention tasks is not robust and may only emerge under specific study conditions (DeLoache & LoBue, 2009; LoBue & DeLoache, 2008). We did not find systematic sex-linked findings with our current sample and analytic strategy. It may be that larger samples, with alternate variables of interest (Burris et al., in press) or more fear-specific stimuli (e.g., spiders), are needed to reveal any emergent differences.

Taken together, our data reveal a complex interaction between maturation (chronological age) and temperament (negative affect) as infants process salient stimuli (dwell time to emotion faces) and subsequently deploy visual attention (fixate to incongruent probes). While age and a growing interest in the salient signal provided by angry faces seems to drive the infants' overall level of initial processing, the impact of processing an angry face on disengagement was associated with temperament as well.

Additional work is needed in order to probe why this relation was not significant for older children. It may be that the general increase in dwell time to angry faces with age simply swamped any individual differences accounted for by temperament. It may also be that parallel developmental processes may have been at play with the older infants. In particular, the broader attention bias literature suggests that high levels of effortful or attentional control can modulate levels of bias and the relation between temperament and bias (C. Cole, Zapp, Fettig, & Perez-Edgar, 2016; Lonigan & Vasey, 2009; Susa, Pitică, Benga, & Miclea, 2012). The first two years of life sees the emergence and rapid increase of child-directed regulatory processes (Rothbart & Rueda, 2005; Rothbart, Sheese, Rueda, & Posner, 2011), which may impact patterns of visual attention. Indeed, recent work (Fu et al., 2017) suggests that effortful control modulates the probability and speed at which high negative affect infants will detect angry faces presented in varying locations across the visual field.

Finally, face processing patterns in the current study may be influenced by broader trends evident in the infant's day-to-day functioning. Jayaraman, Fausey, and Smith (2017) found that the frequency of faces in an infant's field of view decreases in the first two years of life. Thus, the time gazing at faces in view drops from 14 minutes/hour at 3 months to 5 minutes/hour at 18 months, even though their access to people did not decrease. The authors speculated that the change may reflect a developmental shift from face-to-face interactions to more object-centered interactions. Additional work is needed to examine how (or if) these environmental shifts impact lab-based face processing.

The current findings are in line with previous work regarding the attention-response link (Peltola et al., 2015; Pérez-Edgar et al., 2010) suggesting that early appearing differences in attention orienting and control may work to bias development by shaping interactions with, and interpretations of, emotionally-salient components of the environment. Our age-related findings may reflect the rapid, and qualitative, developmental changes in emotion processing occurring in the first two years of life. de Haan & Matheson (2009) note that the recognition of emotions relies on both perceptual and conceptual processing as the infant recognizes distinctions in the stimulus characteristics and then extracts meaning. It is likely that all of the infants in the current study can do the former (Balaban, 1995), but it is unclear when the latter emerges. For example, Oakes and Ellis (2013) found that between 4 and 12 months of age, infants can increasingly scan more features of a face, expanding the amount and type of information they could potentially derive. These scanning differences could reflect maturational differences in cortical control, but are also likely influenced by experiences with faces and the type of information that faces can provide.

Indeed, visual attention reflects infants' increased interest in and awareness of the social value of others, particularly conspecifics. Infants may also be increasingly aware of the high-content value of social and adaptive information conveyed by the face. This is the time period in development during which infants shift from being solely "consumers" of social information, to also become active "seekers" of social input (Carver & Cornew, 2009). Thus, the pattern of bias (dwell time) to angry faces over time may reflect a sample with emerging attention preferences. As Oakes (2015) notes, looking time captures a portion of visual attention processes as well as overlapping biological, cognitive, social systems that contribute to overt attending. Future longitudinal work will be needed with sensitive methods in order to tease these underlying motivational mechanisms apart.

The addition of psychophysiological measures may help in this regard. For example, the event-related potential (ERP), Nc, is seen in the first year of life and displays enhanced amplitude to sustained attention, often accompanied by slowed heart rate (Richards, 2003). The

Nc is thought to reflect the orienting of processing resources to attention-grabbing stimuli (de Haan & Matheson, 2009). Thus, the appearance of the Nc is thought to reflect automatic attention processes, while the modulation of Nc amplitude reflects more controlled application of sustained attention (Martinos et al., 2012). The orienting and modulation marked by the Nc is subserved by the anterior cingulate cortex (ACC), which is in turn thought to regulate limbic activity (de Haan, Johnson, & Halit, 2003; Peltola, Leppanen, Maki, et al., 2009). This emerging neural network, while crude, likely serves as a foundation for entrenched patterns of behavior in childhood and adulthood that link stable attention biases to threat and socioemotional difficulties including anxiety. Future work incorporating the Nc with eye-tracking may place researchers in a better position to follow the emergence and use of multiple attention components over the course of infancy.

Interpretations of the current data should be mindful of study limitations. Our trial-by-trial analysis allowed us to harness all data provided by the infants. However, the number of trials available for each analysis decreases as you drill down to the subset of data supporting the components of the omnibus interaction. This issue may be heightened when performing analyses in which the conditions are defined based on the infant's performance, rather than pre-determined trial parameters. Future studies using this approach should be mindful to maximize the number of available trials in each condition of interest. This concern is somewhat balanced by the fact that the trials retained for analysis are 'cleaner' in that we verified that the infant was indeed engaging in the visual attention behavior *presumed* by the initial task construction. Nonetheless, our novel analyses should be replicated with a highly-powered longitudinal design that can fully test our initial findings and incorporate potential core variables including both temperamental reactivity (negative affect) and regulation (effortful control).

The current cross-sectional data provide preliminary support for both the acquisition model and the moderation model (Field & Lester, 2010). First, a bias to spend greater time visually attending to angry faces emerged with age. No such relation was evident for happy faces. However, when examining latency to incongruent probes within the gaze-defined trial-by-trial mixed effects model, we noted an age by negative affect interaction, such that the impact of temperament is evident among young infants as they attend to angry faces. Longitudinal analyses are needed in order to fully examine potential relations evident in the cross-sectional data.

Finally, with the age range incorporated in the study we were unable to use the same temperament measure across the entire sample. While the questionnaires are similar in format and constructs assessed, there is the potential that the measures may have introduced systematic age-related differences. Nevertheless, our use of eye-tracking technology allowed us to examine patterns of attention to both faces and the probe in young children varying in temperament, as well as explore the impact of initial emotional processing on subsequent behavior. The specificity of these developmental patterns can also be addressed by noting performance with comparable, non-social, stimuli. Parallel work (LoBue et al., 2017) had infants complete two versions of the attention bias task used here. The first version used non-social stimuli varying in putative threat value (i.e., snakes vs. frogs), in line with previous infant studies of early threat detection (LoBue, 2013; LoBue & DeLoache, 2010; LoBue et al., 2014). The second version used face stimuli to represent social threat. All infants showed a bias to non-social threat. The lack of an age effect, and the infants' minimal contact with snakes, suggests that the pattern was due to perceptual sensitivity to the physical features of the threat cues. In contrast, there were age effects to social stimuli, with an increase in latency to cues only after angry face trials. These data suggest a motivational mechanism linked to the social value conveyed by angry faces. Overall, the two studies are in line with recent work with preschoolers (LoBue & Pérez-Edgar, 2014) suggesting that temperamentally shy children, who are often high in negative affect, diverge from their non-shy peers when attending to social threat, but not non-social threat. Again, a fully longitudinal study will be needed to assess how this relation emerges over time.

Attention is a core mechanism of interest in the study of socioemotional development because it both reflects initial reactivity and is an instrument for regulating reactivity (Morales et al., 2016). That is, initially attention may be drawn to an object, person, or event due to immediate salient characteristics, often rooted in perceptual characteristics. In turn, individuals can use attention mechanisms to seek out, engage with, or purposefully disengage from objects, persons, or events that reflect their underlying traits or current motivational concerns. The extent to which attention is—or can be—used for each task will vary as a function of maturation and temperament. This conceptualization of attention parallels our notion of how emotion processes work to regulate children's behavior as well as being a target of regulation (P. M. Cole, Martin, & Dennis, 2004). The current study adds to our understanding of attention as a multifaceted mechanism that is intimately involved in shaping, and reflecting, individual differences in how we navigate a complex social world.

Table 1. Means and standard deviations for demographic and task-based measures. Latency values presented below are based on averages over trials by condition.

	Overall	Included	Excluded
Gender	143/114	82/63	59/51
Age	12.94 (5.55)	12.93** (5.57)	9.33** (5.32)
Negative Affect	0.000 (1.00)	0.082 (1.01)	-0.121 (0.97)
Dwell Time			
Neutral in Angry-Neutral		416.94 (146.36)	--
Neutral in Happy-Neutral		416.71 (152.11)	--
Angry in Angry-Neutral		424.41 (141.84)	--
Happy in Happy-Neutral		411.16 (153.29)	--
Latency to Probe			
Neutral-Neutral		288.27 (97.26)	--
Congruent in Angry-Neutral		301.61 (88.27)	--
Incongruent in Angry-Neutral		305.71 (80.08)	--
Congruent in Happy-Neutral		295.46 (90.41)	--
Incongruent in Happy-Neutral		295.94 (90.83)	--

**p*<0.05, ***p*<0.01 *for included versus excluded; Gender=Male/Female; Age=Months; Time=Milliseconds*

Table 2. Intercorrelations among the central measures in the presented analyses. Degrees of freedom for the r-statistic are noted in parentheses. Values were derived using data averaged across trials in each condition. The mixed methods latency analyses presented in the text and figures employed trial-by-trial analyses, rather than means across trials.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Age	--									
2. Negative Affect	0.104^{+} (244)	--								
3. Dwell Neutral in Angry-Neutral	0.045 (140)	0.038 (134)	--							
4. Dwell Neutral in Happy-Neutral	0.042 (140)	0.097 (134)	0.767^{**} (137)	--						
5. Dwell Angry in Angry-Neutral	0.118 (137)	0.037 (131)	0.775^{*} (134)	0.718^{**} (134)	--					
6. Dwell Happy in Happy-Neutral	0.078 (141)	0.029 (135)	0.787^{**} (138)	0.773^{**} (137)	0.744^{**} (135)	--				
7. Lat. Congruent Angry-Neutral	0.208^{*} (100)	0.086 (95)	0.147 (100)	0.278^{**} (99)	0.260^{**} (100)	0.150 (100)	--			
8. Lat. Incongruent Angry-Neutral	0.349^{**} (101)	0.107 (86)	0.007 (88)	-0.043 (87)	0.002 (86)	-0.072 (88)	0.222^{+} (74)	--		
9. Lat. Congruent Happy-Neutral	0.064 (96)	-0.104 (92)	0.088 (95)	0.030 (95)	0.180^{+} (95)	0.085 (95)	0.504^{**} (82)	0.276^{*} (73)	--	
10. Lat. Incongruent Happy-Neutral	0.088 (95)	-0.054 (91)	0.331^{**} (94)	0.322^{**} (94)	0.075 (94)	0.271^{**} (94)	0.220^{*} (81)	0.201^{+} (72)	0.191^{+} (77)	--

$^{**}p<0.01$; $^{*}p<0.05$; $^{+}p<0.10$

Figure 1. Schematic of the Baby Dot-Probe task used in the current study. Each trial began with a central fixation (a clip from a children's movie), which was presented until the infant fixated for at least 100ms, which was then followed by one of three types of face pairs: Angry-Neutral, Happy-Neutral, and Neutral-Neutral. Faces were presented for 1000 ms, and then replaced by a 500 ms probe. The inter-trial interval was 1000 ms. The illustrated trial presents face stimuli from the NimStim Face Stimulus set (Tottenham et al., 2009) approved for publication.

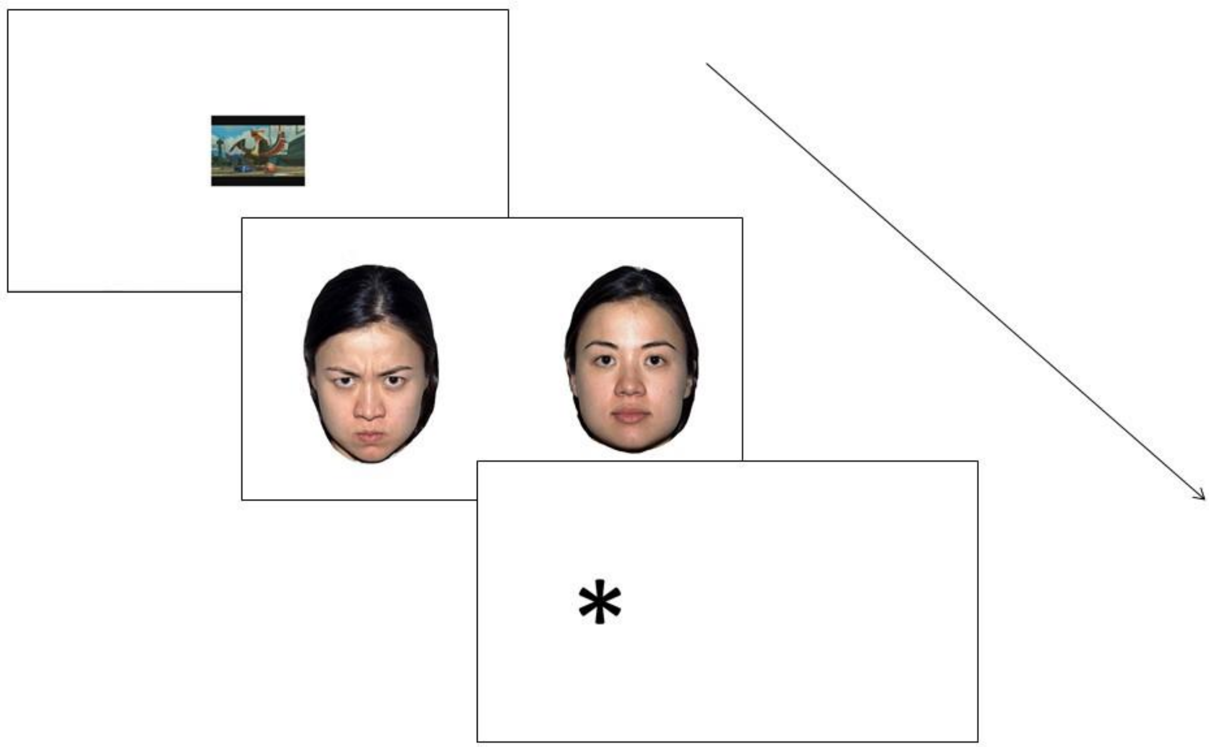


Figure 2. Dwell Time to Angry and Happy faces for infants, presented separately by Age. The values presented are derived from the initial ANCOVA using Dwell Time averaged across trials within each condition, and controlling for Dwell Time to Neutral faces. Given the focus on response to faces in this analysis, task-defined trial designations were used. The Age variable is on the x-axis is standardized.

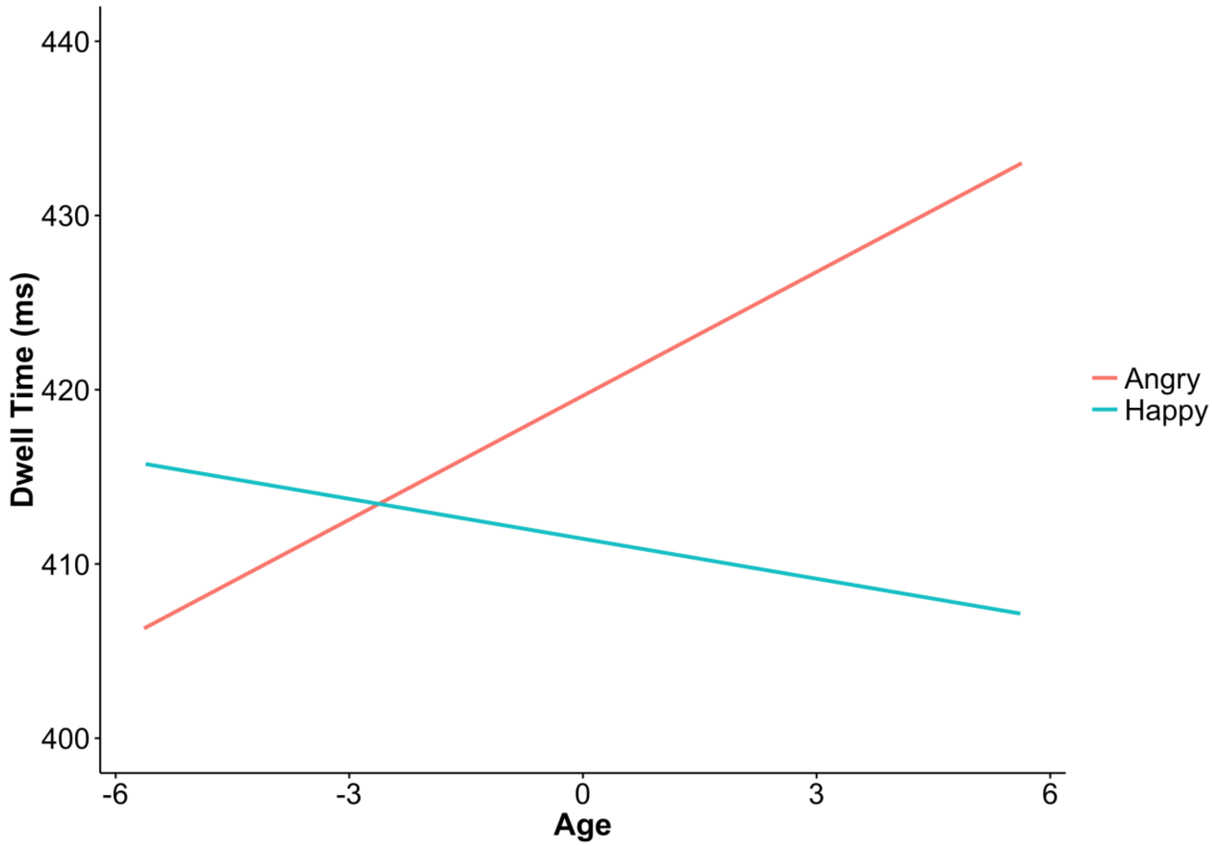


Figure 3. Latencies to fixate the probe for infants, presented separately for from the gaze-defined congruent and incongruent trials and Angry and Happy trials. These analyses used the trial-by-trial designations, re-characterizing congruent and incongruent trials based on observed visual attention.

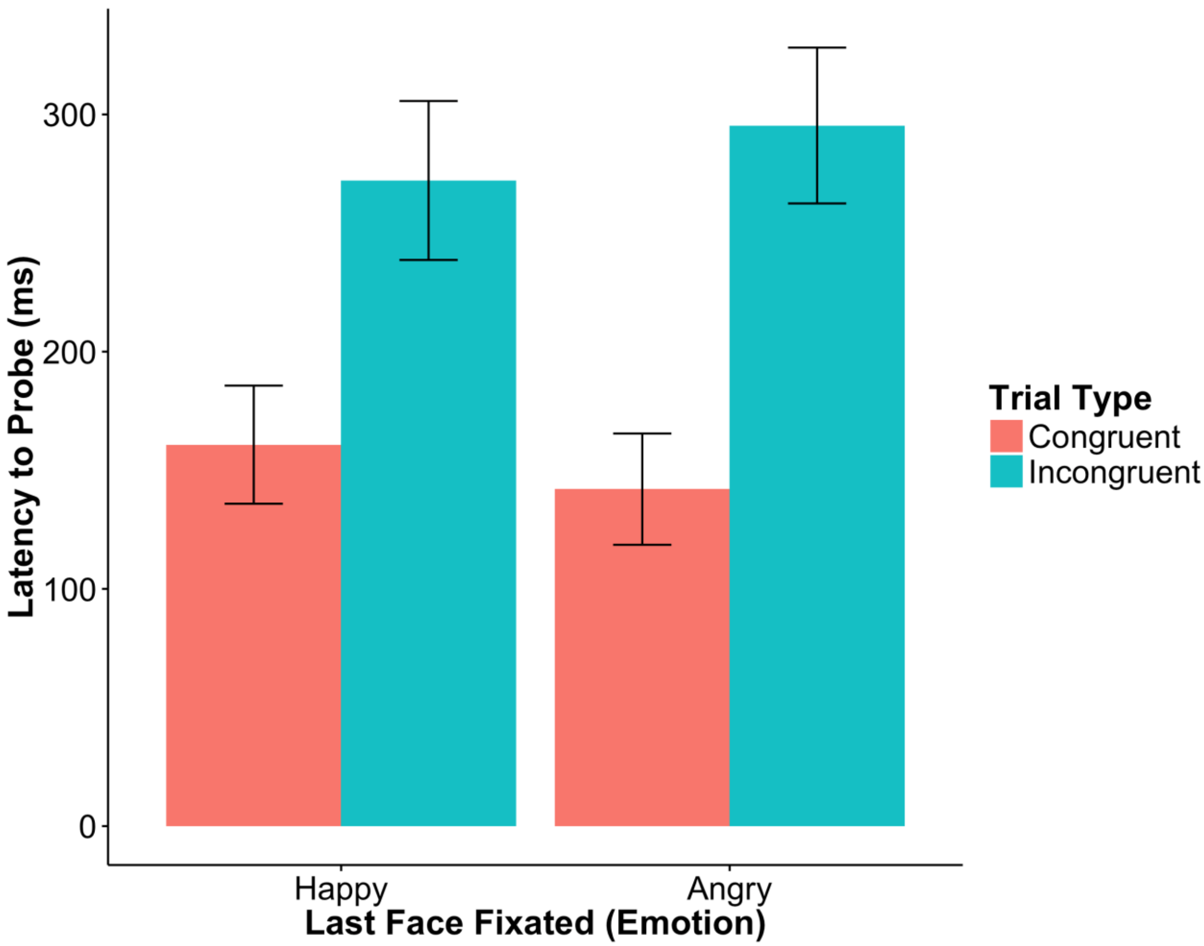
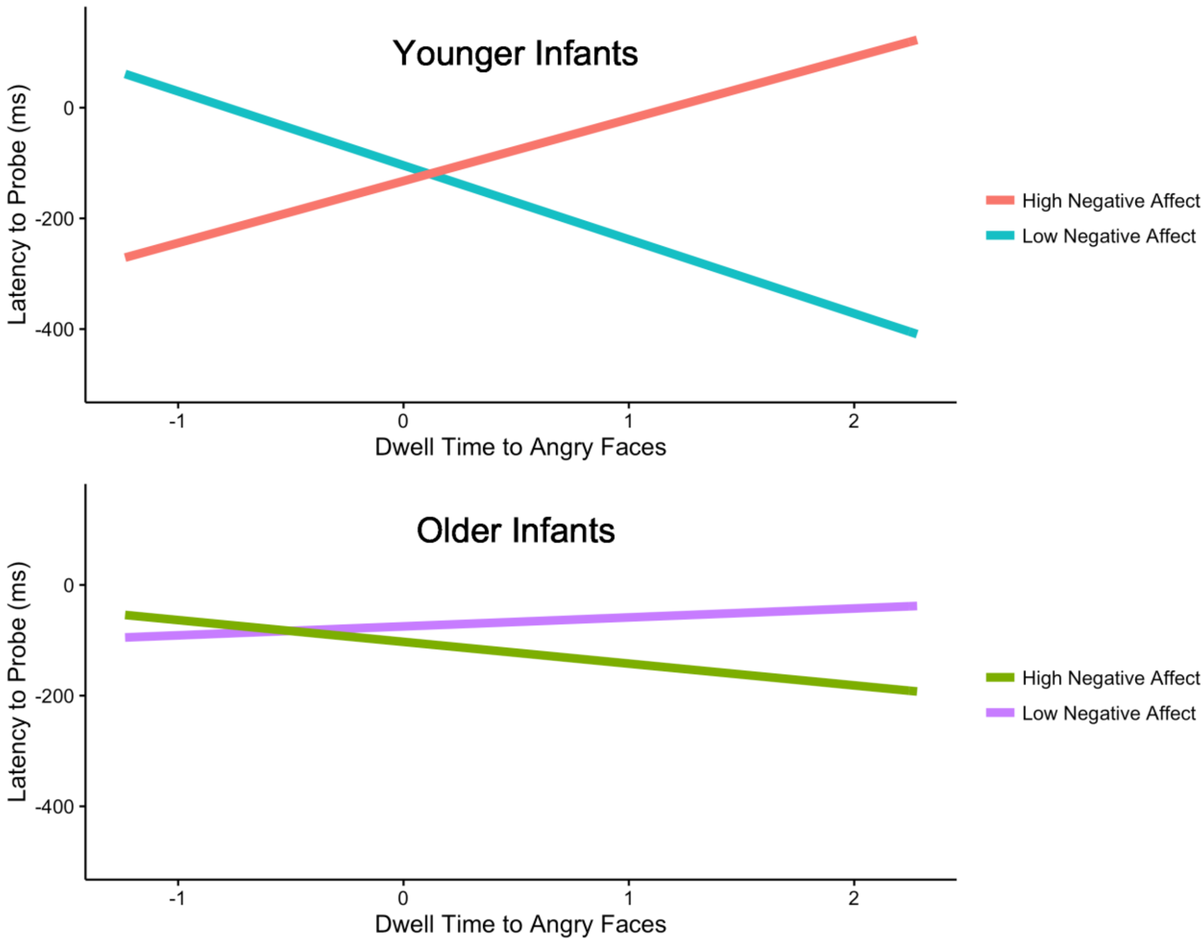


Figure 4. Impact of Dwell Time to Angry faces to Latencies to gaze-defined Incongruent probes that follow, presented separately by Age and Negative Affect. These analyses used the trial-by-trial designations used to re-characterize congruent and incongruent trials based on observed visual attention. For Latency to Probe we control for the timing of the infant's final fixation to the face in the trial prior to the probe presentation. Dwell Time to the Angry faces is standardized. Negative Affect and Age are plotted at +/- 1 SD from the mean.



References

Balaban, M. T. (1995). Affective influences on startle in five-month-old infants: Reactions to facial expressions of emotion. *Child Development, 66*(1), 28-36.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M., & van IJzendoorn, M. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin, 133*, 1-24. doi:10.1037/0033-2909.133.1.1

Belsky, J., & Pluess, M. (2009). Beyond diathesis stress: Differential susceptibility to environmental influences. *Psychological Bulletin, 135*, 885–908.

Brooker, R. J., Neiderhiser, J. M., Ganiban, J. M., Leve, L. D., Shaw, D. S., & Reiss, D. (2014). Birth and adoptive parent anxiety symptoms moderate the link between infant attention control and internalizing problems in toddlerhood. *Development and Psychopathology, 26*(2), 347-359.

Brown, H. M., Eley, T., Broeren, S., MacLeod, C., Rinck, M., Hadwin, J., & Lester, K. (2014). Psychometric properties of reaction time based experimental paradigms measuring anxiety-related information-processing biases in children. *Journal of Anxiety Disorders, 28*(1), 97-107.

Burris, J. L., Barry-Anwar, R. A., & Rivera, S. M. (in press). An eye tracking investigation of attentional biases towards affect in young children. *Developmental Psychology*.

Buss, K. A. (2011). Which fearful toddlers should we worry about? Context, fear regulation, and anxiety risk. *Developmental Psychology, 47*, 804-819.

Buss, K. A., & Kiel, E. J. (2013). Temperamental risk factors for pediatric anxiety disorders. In R. A. Vasa & A. K. Roy (Eds.), *Pediatric Anxiety Disorders: A Clinical Guide* (pp. 47-68). New York: Springer.

Carver, L. J., & Cornew, L. (2009). The development of social information gathering in infancy: A model of neural substrates and developmental mechanisms. In M. de Haan & M. Gunnar (Eds.), *Handbook of Developmental Social Neuroscience* (pp. 122-141). New York: Gulford.

Chronis-Tuscano, A., Degnan, K. A., Pine, D. S., Perez-Edgar, K., Henderson, H. A., Diaz, Y., . . . Fox, N. A. (2009). Stable behavioral inhibition during infancy and early childhood predicts the development of anxiety disorders in adolescence. *Journal of the American Academy of Child & Adolescent Psychiatry, 48*, 928-935. doi:10.1097/CHI.ob013e3181ae09df

Cole, C., Zapp, D. J., Fettig, N. B., & Perez-Edgar, K. (2016). Impact of attention biases to threat and effortful control on individual variations in negative affect and social withdrawal in very young children. *Journal of Experimental Child Psychology, 141*, 210-221.

Cole, P. M., Martin, S. E., & Dennis, T. A. (2004). Emotion regulation as a scientific construct: Methodological challenges and directions for child development research. *Child Development, 75*, 317-333.

Colombo, J. (2001). The development of visual attention in infancy. *Annual Review of Psychology, 52*, 337-367.

Colombo, J., & Salley, B. (2015). Biopsychosocial perspectives on the development of attention in infancy. *Handbook of Infant Biopsychosocial Development* (pp. 71).

de Haan, M., Johnson, M. H., & Halit, H. (2003). Development of face-sensitive event-related potentials during infancy: A review. *International Journal of Psychophysiology, 51*(1), 45-58.

de Haan, M., & Matheson, A. (2009). The development and neural bases of processing emotion in faces and voices. In M. de Haan & M. Gunnar (Eds.), *Handbook of Developmental Social Neuroscience* (pp. 107-120).

DeLoache, J. S., & LoBue, V. (2009). The narrow fellow in the grass: Human infants associate snakes and fear. *Developmental Science, 12*(1), 201-207.

Dudeney, J., Sharpe, L., & Hunt, C. (2015). Attentional bias towards threatening stimuli in children with anxiety: A meta-analysis. *Clinical Psychology Review, 40*, 66-75.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175–191.

Field, A. P., & Lester, K. J. (2010). Is there room for 'development' in developmental models of information processing biases to threat in children and adolescents? *Clinical Child and Family Psychology Review, 13*, 315-332.

Forssman, L., Peltola, M. J., Yrttiaho, S., Puura, K., Mononen, N., Lehtimäki, T., & Leppänen, J. M. (2014). Regulatory variant of the TPH2 gene and early life stress are associated with heightened attention to social signals of fear in infants. *Journal of Child Psychology and Psychiatry, 55*(7), 793-801.

Fox, N. A., Hane, A. A., & Pine, D. S. (2007). Plasticity for affective neurocircuitry: How the environment affects gene expression. *Current Directions in Psychological Science, 16*, 1-5.

Fox, N. A., Henderson, H. A., Rubin, K. H., Calkins, S. D., & Schmidt, L. A. (2001). Continuity and discontinuity of behavioral inhibition and exuberance: Psychophysiological and behavioral influences across the first four years of life. *Child Development, 72*, 1-21. doi:10.1111/1467-8624.00262

Fox, N. A., & Pine, D. S. (2012). Temperament and the emergence of anxiety disorders. *Journal of the American Academy of Child and Adolescent Psychiatry, 51*, 125-128. doi:10.1037//0021-843X.103.1.18

Fox, N. A., Snidman, N., Haas, S. A., Degnan, K. A., & Kagan, J. (2015). The relations between reactivity at 4 months and behavioral inhibition in the second year: Replication across three independent samples. *Infancy, 20*(1), 98-114.

Fu, X., Brown, K. M., Morales, S., LoBue, V., Buss, K. A., & Pérez-Edgar, K. (2017). *Temperament Moderates Vigilance to Emotional Faces in Infants: Evidence from an Eye Tracking Study.* Paper presented at the Biennial Meeting of the Society for Research in Child Development Austin, Texas.

Gartstein, M. A., & Rothbart, M. K. (2003). Studying infant temperament via the Revised Infant Behavior Questionnaire. *Infant Behavior and Development, 26*, 64-86.

Goldsmith, H. H. (1996). Studying temperament via construction of the toddler behavior assessment questionnaire. *Child Development, 67*, 218-235.

Hane, A. A., Fox, N. A., Henderson, H. A., & Marshall, P. J. (2008). Behavioral reactivity and approach-withdrawal bias in infancy. *Developmental Psychology, 44*, 1491-1496.

Henderson, H. A., Fox, N. A., & Rubin, K. H. (2001). Temperamental contributions to social behavior: The moderating roles of frontal EEG asymmetry and gender. *Journal of the American Academy of Child and Adolescent Psychiatry, 40*, 68-74.

Hoehl, S., & Striano, T. (2010). The development of emotional face and eye gaze processing. *Developmental Science, 13*(6), 813-825.
Hood, B., & Atkinson, J. (1993). Disengaging visual attention in the infant and adult. *Infant Behavior and Development, 16*(4), 405-422.
Jayaraman, S., Fausey, C. M., & Smith, L. B. (2017). Way are faces denser in the visual experiences of younger than older infants? *Developmental Psychology, 50*, 38-49.
Kindt, M., Bierman, D., & Brosschot, J. F. (1997). Cognitive bias in spider fear and control children: Assessment of emotional interference by a card format and a single-trial format of the Stroop task. *Journal of Experimental Child Psychology, 66*, 163-179.
Kindt, M., & Brosschot, J. F. (1999). Cognitive bias in spider-phobic children: Comparison of a pictorial and a linguistic spider Stroop. *Journal of Psychopathology & Behavioral Assessment, 21*, 207-220.
Kwon, M. K., Setoodehnia, M., Baek, J., Luck, S. J., & Oakes, L. M. (2016). The development of visual search in infancy: Attention to faces versus salience. *Developmental Psychology, 52*, 537-555.
Leppänen, J. M. (2016). Using eye tracking to understand infants' attentional bias for faces. *Child Development Perspectives, 10*, 161–165.
Leppänen, J. M., & Nelson, C. A. (2006). The development and neural bases of recognizing of facial emotion. In R. Kail (Ed.), *Advances in child development and behavior* (pp. 207-246). London: Elsevier Press.
Leppänen, J. M., & Nelson, C. A. (2009). Tuning the developing brain to social signals of emotions. *Nature Reviews Neuroscience, 10*(1), 37-47.
LoBue, V. (2009). More than just a face in the crowd: Detection of emotional facial expressions in young children and adults. *Developmental Science, 12*, 305-313.
LoBue, V. (2013). What are we so afraid of? How early attention shapes our most common fears. *Child Development Perspectives, 7*, 38–42. doi:10.1111/cdep.12012
LoBue, V., Buss, K. A., Taber-Thomas, B. C., & Pérez-Edgar, K. (2017). Developmental differences in infants' attention to social and non-social threats. *Infancy, 22*, 403-415.
LoBue, V., & DeLoache, J. S. (2008). Detecting the snake in the grass: Attention to fear-relevant stimuli by adults and young children. *Psychological Science, 19*, 284-289.
LoBue, V., & DeLoache, J. S. (2010). Superior detection of threat-relevant stimuli in infancy. *Developmental Science, 13*, 221-228.
LoBue, V., Matthews, K., Harvey, T., & Stark, S. L. (2014). What accounts for the rapid detection of threat? Evidence for an advantage in perceptual and behavioral responding from eye movements. *Emotion, 14*, 816-823.
LoBue, V., & Pérez-Edgar, K. (2014). Sensitivity to social and non-social threats in temperamentally shy children at-risk for anxiety. *Developmental Science, 17*, 239-247.
LoBue, V., Rakison, D., & DeLoache, J. S. (2010). Threat perception across the lifespan: Evidence for multiple converging pathways. *Current Directions in Psychological Science, 19*, 375-379.
Lonigan, C., & Vasey, M. (2009). Negative affectivity, effortful control, and attention to threat-relevant stimuli. *Journal of Abnormal Child Psychology, 37*, 387-399. doi:10.1007/s10802-008-9284-y

Martinos, M., Matheson, A., & de Haan, M. (2012). Links between infant temperament and neurophysiological measures of attention to happy and fearful faces. *Journal of Child Psychology and Psychiatry, 53*(11), 1118-1127.

Mogg, K., Bradley, B. P., De Bono, J., & Painter, M. (1997). Time course of attentional bias for threat information in non-clinical anxiety. *Behaviour Research & Therapy, 35*, 297-303. doi:10.1016/S0005-7967(96)00109-X

Morales, S., Brown, K. M., Taber-Thomas, B. C., LoBue, V., Buss, K. A., & Pérez-Edgar, K. (in press). Maternal anxiety predicts attentional bias towards threat in infancy. *Emotion*.

Morales, S., Fu, X., & Pérez-Edgar, K. (2016). A developmental neuroscience perspective on affect biased attention. *Developmental Cognitive Neuroscience, 21*, 26-41.

Morgante, J. D., Zolfaghari, R., & Johnson, S. P. (2012). A critical test of temporal and spatial accuracy of the Tobii T60XL eye tracker. *Infancy, 17*, 9-32.

Morren, M., Kindt, M., van den Hout, M., & van Kasteren, H. (2003). Anxiety and the processing of threat in children: Further examination of the cognitive inhibition hypothesis. *Behaviour Change, 20*, 131-142.

Nakagawa, A., & Sukigara, M. (2013). Individual differences in disengagement of fixation and temperament: Longitudinal research on toddlers. *Infant Behavior and Development, 36*(4), 728-735.

Oakes, L. M. (2012). Advances in eye tracking in infancy research. *Infancy, 17*, 1-8.

Oakes, L. M. (2015). A biopsychosocial perspective on looking behavior in infancy. In S. D. Calkins (Ed.), *Handbook of Infant Biopsychosocial Development* (pp. 38-70): Guilford Publications.

Oakes, L. M., & Ellis, A. E. (2013). An eye-tracking investigation of developmental chabges in infants' exploration of upright and inverted human faces. *Infancy, 18*(1), 134-148.

Peltola, M. J., Forssman, L., Puura, K., IJzendoorn, M. H., & Leppänen, J. M. (2015). Attention to faces expressing negative emotion at 7 months predicts attachment security at 14 months. *Child Development, 86*(5), 1321–1332.

Peltola, M. J., Hietanen, J. K., Forssman, L., & Leppänen, J. M. (2013). The emergence and stability of the attentional bias to fearful faces in infancy. *Infancy, 18*(6), 905-926.

Peltola, M. J., Leppanen, J. M., Maki, S., & Hietanen, J. K. (2009). Emergence of enhanced attention to fearful faces between 5 and 7 months of age. *Social Cognitive and Affective Neuroscience, 4*, 134-142.

Peltola, M. J., Leppanen, J. M., Palokangas, T., & Hietanen, J. K. (2008). Fearful faces modulate looking duration and attention disengagement in 7-month-old infants. *Developmental Science, 11*, 60-68.

Peltola, M. J., Leppanen, J. M., Vogel-Farley, V. K., Hietanen, J. K., & Nelson, C. A. (2009). Fearful faces but not fearful eyes alone delay attention disengagement in 7-month-old infants. *Emotion, 9*, 560-565.

Pérez-Edgar, K., McDermott, J. M., Korelitz, K., Degnan, K. A., Curby, T. W., Pine, D. S., & Fox, N. A. (2010). Patterns of sustained attention in infancy shape the developmental trajectory of social behavior from toddlerhood through adolescence. *Developmental Psychology, 46*, 1723-1730. doi:10.1037/a0021064

Pérez-Edgar, K., Schmidt, L. A., Henderson, H. A., Schulkin, J., & Fox, N. A. (2008). Salivary cortisol levels and infant temperament shape developmental trajectories in boys at risk for behavioral maladjustment. *Psychoneuroendocrinology, 33*, 916-925.

Pérez-Edgar, K., Taber-Thomas, B., Auday, E., & Morales, S. (2014). Temperament and attention as core mechanisms in the early emergence of anxiety. In K. Lagattuta (Ed.), *Children and Emotion: New Insights into Developmental Affective Science* (Vol. 26, pp. 42-56): Karger Publishing.

Pergamin-Hight, L., Naim, R., Bakermans-Kranenburg, M. J., van IJzendoorn, M. H., & Bar-Haim, Y. (2015). Content specificity of attention bias to threat in anxiety disorders: A meta-analysis. *Clinical Psychology Review, 35*, 10-18.

Petersen, S. E., & Posner, M. I. (2012). The attention system of the human brain: 20 years after. *Annual Review of Neuroscience, 35*, 73.

Posner, M. I., & Rothbart, M. K. (2007). Research on attention networks as a model for the integration of psychological science. *Annual Review of Psychology, 58*, 1-23. doi:10.1146/annurev.psych.58.110405.085516

Quinn, P. C. (2011). Born to categorize. In U. Goswami (Ed.), *The Wiley-Blackwell Handbook of Childhood Cognitive Development* (pp. 129-152). West Sussex, UK: Wiley-Blackwell.

Rakison, D. H. (2009). Does women's greater fear of snakes and spiders originate in infancy? *Evolution and Human Behavior, 30*(6), 438-444.

Ravicz, M. M., Perdue, K. L., Westerlund, A., Vanderwert, R. E., & Nelson, C. A. (2015). Infants' neural responses to facial emotion in the prefrontal cortex are correlated with temperament: A functional near-infrared spectroscopy study. *Frontiers in Psychology, 6*, 922.

Richards, J. E. (2003). Attention affects the recognition of briefly presented visual stimuli in infants: An ERP study. *Developmental Science, 6*(3), 312-328.

Rodebaugh, T. L., Scullin, R. B., Langer, J. K., Dixon, D. J., Huppert, J. D., Bernstein, A., . . . Lenze, E. J. (2016). Unreliability as a threat to understanding psychopathology: The cautionary tale of attentional bias. *Journal of Abnormal Psychology, 125*, 840-851.

Rothbart, M. K., Posner, M. I., & Rosicky, J. (1994). Orienting in normal and pathological development. *Development and Psychopathology, 6*, 635-652. doi:10.1017/S0954579400004715

Rothbart, M. K., & Rueda, M. R. (2005). The development of effortful control. In U. Mayr, E. Awh, & S. Keele (Eds.), *Developing individuality in the human brain: A tribute to Michael I. Posner* (pp. 167-188). Washington, D.C.: American Psychological Association.

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

Roy, A. K., Dennis, T. A., & Warner, C. M. (2015). A critical review of attentional threat bias and its role in the treatment of pediatric anxiety disorders. *Journal of Cognitive Psychotherapy, 29*(3), 171-184.

Scerif, G. (2010). Attention trajectories, mechanisms and outcomes: At the interface between developing cognition and environment. *Developmental Science, 13*, 805-812.

Sheese, B. E., Rothbart, M. K., Posner, M. I., White, L. K., & Fraundorf, S. H. (2008). Executive attention and self-regulation in infancy. *Infant Behavior and Development, 31*, 501-510.

Stets, M., Stahl, D., & Reid, V. M. (2012). A meta-analysis investigating factors underlying attrition rates in infant ERP studies. *Developmental Neuropsychology, 37*, 226-252.

Susa, G., Pitică, I., Benga, O., & Miclea, M. (2012). The self regulatory effect of attentional control in modulating the relationship between attentional biases toward threat and anxiety symptoms in children. *Cognition & Emotion, 26*, 1069-1083. doi:10.1080/02699931.2011.638910

Todd, R. M., Cunningham, W. A., Anderson, A. K., & Thompson, E. (2012). Affect-biased attention as emotion regulation. *Trends in Cognitive Sciences, 16*, 365-372. doi:10.1016/j.tics.2012.06.003

Tottenham, N., Tanaka, J., Leon, A., McCarry, T., Nurse, M., Hare, T., . . . Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research, 168*, 242-249. doi:10.1016/j.psychres.2008.05.006

Uchiyama, I., Anderson, D. I., Campos, J. J., Witherington, D., Frankel, C. B., Lejeune, L., & Barbu-Roth, M. (2008). Locomotor experience affects self and emotion. *Developmental Psychology, 44*(5), 1225.

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