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Variability in caregiver attention bias to threat: A Goldilocks effect in infant emotional development?

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Abstract

Attention biases to threat are considered part of the etiology of anxiety disorders. Attention bias variability (ABV) quantifies intraindividual fluctuations in attention biases and may better capture the relation between attention biases and psychopathology risk versus mean levels of attention bias. ABV to threat has been associated with attentional control and emotion regulation, which may impact how caregivers interact with their child. In a relatively diverse sample of infants (50% White, 50.7% female), we asked how caregiver ABV to threat related to trajectories of infant negative affect across the first 2 years of life. Families were part of a multi-site longitudinal study, and data were collected from 4 to 24 months of age. Multilevel modeling examined the effect of average caregiver attention biases on changes in negative affect. We found a significant interaction between infant age and caregiver ABV to threat. Probing this interaction revealed that infants of caregivers with high ABV showed decreases in negative affect over time, while infants of caregivers with low-to-average ABV showed potentiated increases in negative affect. We discuss how both high and *extreme* patterns of ABV may relate to deviations in developmental trajectories.

Keywords: attention bias to threat; attention bias variability; dot probe; infant development; negative affect

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Introduction

Attention biases to threatening stimuli are thought to be part of the etiology of anxiety disorders (Roy et al., 2008). Persistent attention to threat, particularly when marked by low thresholds for threat detection, may underscore information processing biases leading to, or reinforcing, disorder (Roy et al., 2008).

A standard task used to assess attention biases to threat is the dot-probe paradigm (MacLeod et al., 1986). In this task, participants are presented with an emotionally valenced cue paired with a cue of neutral valence (e.g., one angry facial configuration, one neutral configuration) on a computer screen. These stimuli disappear and one of cues is replaced with a "probe." The participant is asked to respond by noting the probe's location or identity, usually with a motor response, such as a button press. The latency to respond to the probe in the salient cue's (e.g., angry) prior location versus probes in the control cue's (e.g., neutral) location is thought to index the magnitude of an attentional bias to the emotional cue (MacLeod et al., 1986).

However, much discussion has emerged regarding the actual utility of the dot-probe task. Concerns have been raised regarding both internal reliability, seen in split-half and test–retest calculations (Chapman et al., 2019; Price et al., 2015; Schmukle, 2005), and predictive validity, such as inconsistency in associations between task performance and levels of anxiety (Kappenman et al., 2014). In addition, participants vary greatly within their own responses on a trial-by-trial level (Price et al., 2015). Many cite this within-person variability as a shortcoming of the task, contributing to broader psychometric concerns (Chapman et al., 2019; Price et al., 2015; Staugaard, 2009).

Importantly, attention biases are not a static construct (Gunther, Brown, et al., 2021; Gunther, Fu, et al., 2021) and intra-individual variability *within* the task may be meaningful in understanding individual differences in affect-biased attention (Price et al., 2015). Attention bias variability (ABV) provides a metric capturing the degree of intraindividual variability within a task session. In contrast to traditional dot-probe metrics, ABV offers much improved reliability (Price et al., 2015). In the present study, we examined how traditional bias scores and ABV metrics among mothers may differentially predict changes in infant socioemotional development in the first 2 years of life.

Broadly, ABV is thought to capture inconsistency in vigilance/avoidance responses to emotionally valenced stimuli (Price et al., 2015). Inconsistency may be associated with individual differences in regulatory behaviors including emotion regulation or attentional control, which may be transdiagnostic risk factors for psychopathology (Cludius et al., 2020; Dadds & Frick, 2019; McTeague et al., 2016). For example, Bardeen et al. (2017) found a positive relation between emotion dysregulation and ABV to threatening pictures in a community sample of adults. Deficits in emotion regulation may be a risk factor for potentially maladaptive patterns of behavior, such as anxiety and aggression (McLaughlin et al., 2011). Additionally, attentional control mediated the relation between ABV and anxiety in one sample

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of adults (Clarke et al., 2020) and the relation between ABV and post-traumatic stress disorder (PTSD) symptomology was mediated by emotion regulation abilities in another sample (Klanecky Earl et al., 2020). Further, Bardeen et al. (2016) found that attentional control *moderated* the relation between ABV and PTSD, where individuals with both PTSD and lower levels of attentional control had greater ABV to threatening stimuli, but individuals with PTSD and higher levels of attentional control had lower ABV. Together, these findings suggest ABV may be related to more general cognitive processes such as emotion regulation and attentional control, which are often captured as mean-level variables.

We also see direct associations between ABV and psychopathology. ABV is associated with disorders that are often linked to attention biases to threat, including PTSD and anxiety. Individuals with PTSD, for example, are often characterized in part by a hypervigilance to threat. Among individuals with PTSD, ABV to threat-related cues is positively related to symptom severity (Badura-Brack et al., 2015; Bardeen et al., 2016; Iacoviello et al., 2014; Naim et al., 2015; Swick & Ashley, 2017).

However, studies on the direct associations between ABV and anxiety disorders are not always consistent. Some work finds no relation between a formal anxiety diagnosis and ABV to threatening stimuli (Gade et al., 2021; Naim et al., 2015) or subclinical levels of trait anxiety and ABV to threat (Naim et al., 2015). In contrast, Clarke and colleagues (2020) found that greater ABV to negative words compared to neutral words was positively associated with reported anxiety symptoms in a community sample of adults. These findings also extend to phobias. Zvielli et al. (2015) examined ABV in adults reporting a spider phobia who completed a dot-probe task with spiders and butterflies. They found that greater ABV to the spider trials was associated with a spider phobia. Together, these findings suggest that ABV may relate broadly to psychopathologies characterized in part by extreme patterns of responses to identified threats.

While prior research has focused on how ABV to threat relates to psychopathology or risk within the individual, there is a paucity of work examining how these attentional patterns may impact relationships. The broader literature suggests that ABV may be related to individual psychopathology, such as anxiety disorders. The parenting literature, in turn, has shown strong relations between caregiver anxiety symptoms and socioemotional difficulties in their offspring (Barker et al., 2011; Glasheen et al., 2009). By examining relations between ABV and infant negative affect, a risk factor for anxiety, we are examining a potential proximal mechanism that may help us better understand the etiology of associations between caregiver and child psychopathology.

While work with ABV is still emerging, the research reviewed above suggests that ABV relates to variation in attentional control and/or emotion regulation. Attentional control and emotion regulation, although distinct, have each been associated with the way in which an individual structures their home environment (Bridgett et al., 2013) and the way caregivers interact with their infants (Geeraerts et al., 2021). These profiles are also related to more chaotic households (Bridgett et al., 2013; Mokrova et al., 2010) and inconsistent parenting (Murray & Johnston, 2006). A parent's ability to regulate their emotions may also relate to their responsiveness to their child (Dix, 1991) or the ways in which they discipline their child (Lorber & Slep, 2005). For example, a caregiver with high attentional control may structure an organized household. Similarly, a caregiver with high attentional control and/or high emotion regulation may also be more likely to respond positively to their child's behavior, as they are able to better regulate their own negative emotions when their child behaves in a way that may be undesirable or unexpected.

For a caregiver with lower levels of attentional control or emotion regulation, we could expect a more chaotic household and a higher propensity to respond negatively to their child's behavior, as these regulatory processes and behaviors may be more effortful and less readily called upon (Bridgett et al., 2013; Geeraerts et al., 2021). Conversely, *over*controlled behaviors may also have negative implications within a household, contributing to increased risk for internalizing disorders for the caregiver (Gilbert et al., 2020; Henderson et al., 2015; Henderson & Wilson, 2017; White et al., 2011) as well as patterns of rigid parenting behaviors such as overprotection (Kiel & Buss, 2010, 2011).

Here, we view interactions between the caregiver and child through the lens of Bronfenbrenner's bioecological model (Bronfenbrenner & Morris, 2007). In this approach, a child's development is shaped by the environment in which a child exists, and interactions between different "systems" that encompass their environment. The microsystem refers to the most proximal space in which a child develops, including their home and family. The literature suggests that ABV may reflect regulatory processes in attentional and emotional domains that are in turn associated with how a child's microsystem is structured. Here we focus on the potential that caregiver ABV may be associated with the developmental trajectories of the children they care for. Assessing how caregiver ABV to threat may relate to developmental changes in child socioemotional development tests a novel attentional mechanism of parent-to-child transmission of psychopathology risk. We are particularly interested in how ABV may relate to socioemotional development during infancy, a period in which a child is particularly reliant on their caregiver for shaping both their physical and social world. Infancy is also a period of heightened plasticity (Guyer et al., 2018), when neural networks that support attention emerge and functionally integrate, reflecting adult-like patterns by 12 months (Gao et al., 2013). Thus, this developmental phase is one of increased malleability as a function of environmental context (Guyer et al., 2018).

In this study, we examined how caregiver ABV to threat is related to infant negative affect over the first 2 years of life. Negative affect is a temperamental risk factor for psychopathology that is evident in the first months of life. While prior work finds normative increases in negative affect through infancy (Braungart-Rieker et al., 2010; Dollar & Calkins, 2019), relatively high levels of negative affect are a risk factor for socioemotional maladaptation later in childhood and adolescence, including depression and anxiety (Lonigan et al., 2003). High levels of infant negative affect are also associated with a behaviorally inhibited temperament, which is a risk factor for social anxiety disorder (Calkins et al., 1996; Chronis-Tuscano et al., 2009). Understanding the relation between ABV to threat and infant/toddler negative affect may help to better elucidate a mechanism for the intergenerational transmission of psychopathology.

Prior work with ABV has been conducted exclusively with button press reaction time. However, eye-tracking metrics of attention bias appear to have better reliability and validity, relative to button press (Price et al., 2015; Waechter et al., 2014). In addition, eye-tracking may help reveal attentional processes, such as preferential viewing of the emotional stimuli used in the task, and more reflexive patterns of orienting that precede the recorded button press. Here, we leverage eye-tracking technology to examine ABV to threat during the dot-probe task, using both button presses and fixation latencies.

Our main question of interest examines how ABV to threat in a sample of parents may relate to trajectories of infant negative affect. We also assess the traditional attention bias score typically derived from the dot-probe task, to interrogate the specificity of these relations. We hypothesized that infants of caregivers with higher button press ABV would have potentiated increases in negative affect across the first 2 years of life. We predicted that bias scores, the more traditional dot-probe metric, would not significantly relate to infant negative affect over time. Because the fixation ABV measure was a novel computation not used in prior work, we had no specific hypotheses for this metric and analyses were exploratory.

Methods

Participants

Participants were selected from a larger longitudinal sample ($N = 357$) assessing the emergence of attention and temperament through infancy and toddlerhood (Pérez-Edgar et al., 2021). Data were collected from infants at 4, 8, 12, 18, and 24 months, using a multi-method approach. A comprehensive list of all measures collected from this sample can be found in Pérez-Edgar et al., 2021. For the current project, primary caregivers completed an emotional dot-probe task with concurrent eye-tracking at all 5 timepoints. They also reported on their infant's temperament via questionnaire measures. The Institutional Review Boards at the Pennsylvania State University and Rutgers University – Newark approved all procedures and parents provided written consent and were compensated for their participation.

Of the larger sample, participants were recruited through local baby registries (40% families) and university-sponsored participant databases (13% families). In addition, we used a variety of community-level recruitment strategies, such as visiting local lactation/parenting classes, communicating with families at local community events, and talking to parents at local hospitals, health care centers, and Women's and Infant Centers (WIC). Community recruiting identified 38% of our families. Prospective families were contacted by letter, email, or phone explaining the motivations and methods of the study. The remaining 10% of families were recruited by word-of-mouth. These families were either referred by enrolled participants, referred by the researchers, or were graduate students at each of the universities.

Infants and their caregivers were enrolled when the infants were 4 months of age ($N = 298$; 151 males, 147 females; $M_{age} = 4.80$ months; $SD_{age} = 0.80$, $Range_{age} = 3.27$–7.60 months), with an additional 46 participants enrolled at 8 months ($N = 46$; 19 males, 27 females; $M_{age} = 8.83$ months; $SD_{age} = 0.73$, $Range_{age} = 7.53$–10.20 months), and 13 at 12 months ($N = 13$; 6 males, 7 females; $M_{age} = 12.73$ months; $SD_{age} = 1.12$, $Range_{age} = 10.63$–14.90 months, for a total enrollment of 357 infants in the full sample (176 males, 181 females). Participants were recruited from areas surrounding three sites: State College, PA ($N = 167$), Harrisburg, PA ($N = 81$) and Newark, NJ ($N = 109$). Caregivers identified 58 of the infants (16%) as African American/Black, 9 (3%) as Asian, 78 (22%) as Latinx, 180 (50%) as White, and 27 (8%) as mixed race. Five (1%) additional caregivers declined to provide this information. 99% of respondents identified as the infant's biological parent ($N = 5$ reporting something other than biological parent). The participating parent at each time point self-identified as the primary caregiver, and post hoc data cleaning ensured that the same caregiver completed the eye-tracking task at each analyzed timepoint.

Caregivers were asked to report on their annual household income, as well as maternal and paternal education. This information, for the entire sample as well as for each site, can be found in Table 1.

Of this larger sample ($n = 357$), inclusion in analysis depended on variables collected from families. The model assessing button press ABV ($n = 239$), the model assessing fixation-based ABV ($n = 214$), and the model using a traditional threat bias score ($n = 249$) each contained a slightly different sample based on data availability and quality.

Data collection began on October 31, 2016 and continued until August 17, 2021. Infants and their parents scheduled for visits after March 11, 2020 (World Health Organization's declaration of the COVID-19 global pandemic) did not come into the lab and instead were sent questionnaires via email. Data that required in-person, in-lab interactions, like the dot-probe task, were treated as missing data for applicable participants. Of the 357 individuals enrolled in the larger study, 200 completed all five time points of data collection prior to March 11, 2020. The remaining 157 participants did not complete participation by this time and therefore attempts were made to collect questionnaire data remotely.

Measures

Adult dot-probe

An adaptation of the standard dot-probe task, designed to assess attentional biases (MacLeod et al., 1986), was presented to the infants' caregivers, relying on both gaze and button presses to assess attention biases. Eye-tracking data were collected across sites using SMI eye-tracking systems, using 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. Gaze was calibrated using a 5-point calibration followed by a 4-point validation. Gaze data was sampled at 60 Hz and collected by Experiment Center (SensoMotoric Instruments, Teltow, Germany). Adults were calibrated below 2° of visual angle deviation from all calibration points.

Consistent with the calibration procedure, stimuli were presented using Experiment Center. Adults were presented with 160 experimental trials. Each trial began with a centrally presented fixation cross for 500 ms. Following was a horizontal pair of faces sampled from the NimStim face set (Tottenham et al., 2009) for 500ms. Pairs of faces were either angry and neutral, happy and neutral, or two neutral faces. Facial stimuli were approximately 19 cm × 13 cm and the visual angle of each face was 17.99° (H) × 12.37° (W). The faces were 24.45° apart. Eight actors (four male) provided neutral, happy, or angry, closed mouth images.

Next, a "probe" appeared on the screen in the same location as either the left or right face for 500 ms. The probes were two dots that were either horizontally or vertically. Participants were prompted to press the "D" button on a keyboard if the dots were horizontal, and the "K" button if the dots were vertical. If the probe appeared in the same location as the "emotional" (i.e., angry or happy) face, the trial was marked as "congruent." Conversely, if the probe appeared in the same location as the neutral face, the trial

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Table 1. Table summarizing demographics of whole sample, as well as parsed by testing location

Measure	Whole sample ($n = 357$)	State College, PA ($n = 167$)	Harrisburg, PA ($n = 81$)	Newark, NJ ($n = 109$)
Sex				
Female	181 (50.7%)	84 (50%)	37 (46%)	60 (55%)
Race/Ethnicity				
Asian	9 (3%)	7 (4%)	0 (0%)	2 (2%)
Black	58 (16%)	0 (0%)	21 (26%)	37 (34%)
Latinx	78 (22%)	9 (5%)	9 (11%)	60 (55%)
White	180 (50%)	133 (80%)	39 (48%)	8 (7%)
More than one reported	27 (8%)	15 (9%)	11 (14%)	1 (1%)
Declined to answer	5 (1%)	3 (2%)	1 (1%)	1 (1%)
Household income				
$15,000 or less	49 (14%)	5 (3%)	12 (15%)	32 (29%)
$16,000–$20,000	20 (6%)	2 (1%)	5 (6%)	13 (12%)
$21,000–$30,000	22 (6%)	6 (4%)	6 (7%)	10 (9%)
$31,000–$40,000	16 (5%)	7 (4%)	7 (9%)	2 (2%)
$41,000–$50,000	22 (6%)	15 (9%)	3 (4%)	4 (4%)
$51,000–$60,000	29 (8%)	21 (13%)	5 (6%)	3 (3%)
Above $60,000	140 (39%)	99 (59%)	34 (42%)	7 (6%)
Declined to answer	59 (17%)	12 (7%)	9 (11%)	38 (35%)
Maternal education				
Grade school only	11 (3%)	0 (0%)	0 (0%)	11 (10%)
Some high school	1 (5%)	1 (1%)	6 (7%)	10 (9%)
High school graduate	36 (10%)	8 (5%)	12 (15%)	16 (15%)
Some college/trade degree	57 (16%)	15 (9%)	20 (25%)	22 (20%)
College graduate	73 (20%)	47 (28%)	16 (20%)	10 (9%)
Graduate training	58 (16%)	39 (23%)	14 (17%)	5 (5%)
Graduate degree	66 (19%)	53 (32%)	7 (8%)	6 (6%)
Declined to answer	39 (11%)	4 (2%)	6 (8%)	29 (26%)
Paternal education				
Grade school only	11 (3%)	0 (0%)	0 (0%)	11 (10%)
Some high school	15 (4%)	2 (1%)	5 (6%)	8 (7%)
High school graduate	50 (14%)	9 (5%)	22 (27%)	19 (17%)
Some college/trade degree	60 (17%)	24 (14%)	21 (26%)	15 (14%)
College graduate	70 (20%)	51 (31%)	13 (16%)	6 (6%)
Graduate training	42 (12%)	30 (18%)	5 (6%)	7 (6%)
Graduate degree	56 (16%)	44 (26%)	8 (10%)	4 (4%)
Declined to answer	53 (15%)	7 (4%)	7 (9%)	39 (36%)
Data collected pre-COVID	200 (56%)	105 (63%)	40 (49%)	55 (51%)

was marked as "incongruent." This generated a total of five different trial types: angry-congruent, angry incongruent, happy congruent, happy incongruent, or neutral. Finally, the trial was concluded with a 1,000 ms intertrial interval, which was a blank screen. Figure 1 depicts the progression of stimuli for each trial of the task.

Areas of interest (AOIs) were drawn as ellipses enclosing both the faces and the probes. A 1 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 80ms within a 100-pixel maximum dispersion, were extracted

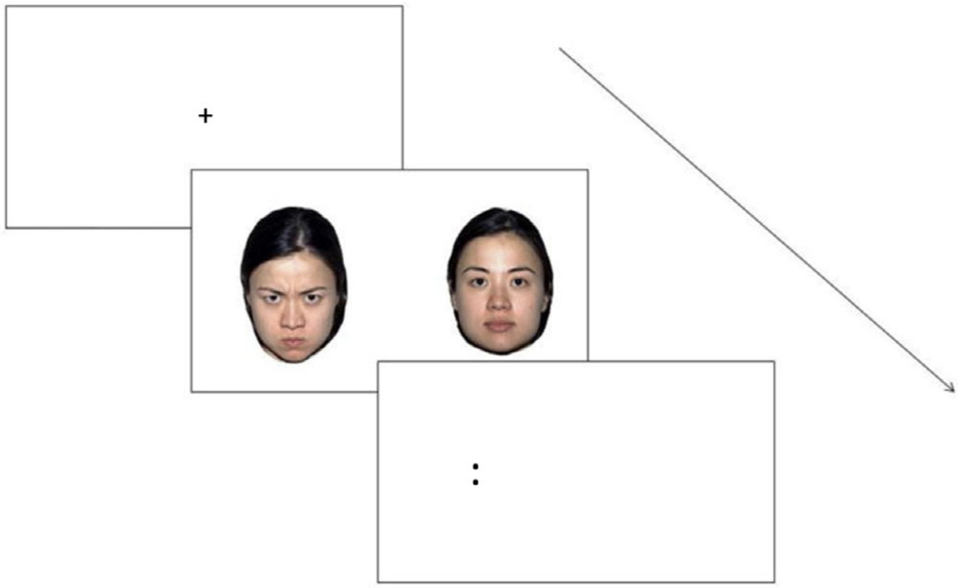

Figure 1. Schematic of the dot-probe task used to calculate ABV. Each trial began with a central fixation cross (500 ms) followed by paired faces of a neutral and emotionally valenced face (500 ms). Finally, one face was replaced by a probe, either two horizontal dots or vertical dots (500 ms). During this window, participants were asked to indicate the orientation of the dots. The intertrial interval was 1000 ms. The illustrated trial presents face stimuli from the NimStim Face Stimulus set (Tottenham et al., 2009) approved for publication.

with BeGaze (SensoMotoric Instruments, Teltow, Germany). All other computations of gaze metrics were performed using in-house R scripts (R Core Team, 2020).

Metrics were cleaned on a trial-by-trial level. For button press data, only correct trials were used in subsequent computations. RT latencies less than 150 ms and greater than 2,000 ms were excluded from the final data set. Finally, for gaze data, if a fixation was not detected to the probe during a trial, that trial was not included (Fu et al., 2017; Morales et al., 2015; Thai et al., 2016). Even with these criteria, a relatively large proportion of trials were retained for analyses. Across the five time points, an average ranging from 137.86 to 141.19 trials (out of 160) were retained for gaze analyses and an average ranging from 132.16 to 146.07 trials (out of 160) were retained for analyses using button presses.

For these analyses we were most interested in responses to angry faces. ABV for trials with angry faces was calculated using button press reaction times, according to Zvielli et al. (2015) using custom scripts in a combination of Matlab release 2017b (Matlab, 2017) and R version 3.6.2 (R Core Team, 2020). In this computation, trial-level bias scores were calculated by subtracting the response time latencies of temporally adjacent pairs (within ± 5 trials) of angry-congruent and angry-incongruent trials, that is trials in which the probe was in the same and opposite location as the angry face, respectively. From trial-level bias scores, the ABV metric was derived by dividing the sum of all trial-level bias scores by the number of temporally adjacent pairs. Additional details on these computations can be found in Zvielli et al (2015). Additionally, as a novel computation, we used the same ABV calculation using latency to fixate on the probe, as opposed to the button press reaction time. Finally, angry bias scores, a traditional dot-probe metric, were calculated from the button press data. This was done by subtracting the average reaction time to respond on angry-congruent trials, from the average reaction time to respond to angry-incongruent trials.

Within each of these measures, we examined the data for extreme values that were likely attributed to measurement error rather than individual differences. We removed one value from the data set of button press ABV, and one value from the data set of eye-tracking ABV, determined using visual inspection of a scatter plot, before moving forward with subsequent analyses.

Infant negative affect

The Infant Behavior Questionnaire (IBQ-R) was used to measure negative affect at 4, 8, and 12 months. The IBQ-R is a 191-item survey designed to assess general patterns of behavior associated with temperament in infancy (3–12 months; Parade & Leerkes, 2008; Putnam et al., 2014). Parents rated how often they observed a behavior in the past week. Each item describes an infant's behavior (e.g., *During feeding, how often did the baby lie or sit quietly?*) using a 7-point 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. We focused analyses upon the negativity factor, one of three broader factors derived from the questionnaire. Sadness, distress to limitations, fear, and falling reactivity subscales load onto this factor. 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). Across the full sample, IBQ reliabilities were good at 4 months (Cronbach's alpha = 0.776–0.953), 8 months (Cronbach's alpha = 0.728–0.943), and 12 months (Cronbach's alpha = 0.767–0.922).

The Toddler Behavior Assessment Questionnaire (TBAQ) was used to measure infant negative affect at 18 and 24 months. The TBAQ is a 120-item survey designed to assess general patterns of behavior associated with temperament in young children (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. Where the TBAQ does not have an explicit negative affect subscale, Goldsmith (1996) reported high levels of convergence with various subscales of the IBQ. Thus, in line with prior publications (e.g., Vallorani et al., 2021), we generated our own negative affect subscale by using the anger, sadness, social fear, and object fear subscales. Reliabilities across TBAQ subscales were good (Cronbach's alpha = 0.612–0.850).

Caregiver anxiety

The Beck Anxiety Inventory (BAI) is a 21-item self-report questionnaire for evaluating the severity of anxiety in healthy and psychiatric populations (Beck et al., 1988a). It was collected at the 4-, 8-, 12-, 18-, and 24-month time points. The BAI was specifically designed to distinguish cognitive and somatic symptoms of anxiety from symptoms of depression. Parents rated individual symptoms of anxiety (e.g., fear of losing control) in the past month using a 4-point Likert scale (0 = not at all, 1 = mildly, 2 = moderately, 3 = severely). The BAI is scored by adding the highest ratings for all 21 items, for a score range from 0 to 63. Higher scores indicate greater symptom severity. Good psychometric properties have been demonstrated for the BAI among multiple outpatient samples (Morin et al., 1999; Steer et al., 1994; Wetherell & Areán, 1997). Internal consistency of the measure for the total sample was strong across time points ($\alpha_{4\text{-}months} = 0.91$, $\alpha_{8\text{-}months} = 0.89$, $\alpha_{12\text{-}months} = 0.93$, $\alpha_{18\text{-}months} = 0.94$, $\alpha_{24\text{-}months} = 0.92$) and adequate test–retest reliability has been demonstrated for anxiety patients ($r = 0.75$ to 0.83; Beck et al., 1988b; de Beurs et al., 1997). The measure is also moderately correlated with anxiety ($r = 0.36$ to 0.69) and depression measures ($r = 0.25$ to 0.56) completed by psychiatric (Beck et al., 1988a) and normative samples (Osman et al., 1997). We considered caregiver anxiety in characterizing our sample and as a covariate in analyses (see below) due to prior work suggesting possible associations between anxiety and ABV in adults (Clarke et al., 2020).

Data analysis

We first sought to characterize our metrics of caregiver threat attention within this sample to examine stability and fluctuations in threat attention over time. Because ABV is associated with trait-like constructs including regulation and psychopathology (Bardeen et al., 2016, 2017; Clarke et al., 2020; Klanecky Earl et al., 2020; Zvielli et al., 2015), from a theoretical basis we hypothesized that ABV would be relatively stable over time. We ran a conditional growth model to test whether the mother's ABV to threat changed as a function of infant age (between 4 and 24 months postpartum). For consistency across our three metrics of interest, we also ran and examined additional growth models for fixation ABV to threat as well as threat bias scores. We found that infant age did not significantly predict button press or gaze ABV to threat ($p = 0.40$ and $p = 0.52$, respectively) or threat bias scores ($p = 0.13$). Figure 2 depicts distribution of the button press ABV metric at each measurement timepoint.

As a follow-up we computed intraclass coefficients (ICCs) for each metric (Koo & Li, 2016). We found that the ICC for button press ABV to threat was good (ICC = 0.75, 95% CI 0.710.79) and the ICC for gaze ABV to threat was moderate (ICC = 0.47, 95% CI 0.38–0.55). Unsurprisingly, in light of research finding low test-retest reliability for bias scores in the dot probe (Chapman et al., 2019; Price et al., 2015; Schmukle, 2005), the ICC for threat bias scores was poor (ICC = 0.11, 95% CI −0.04, 0.23). With our theoretical orientation as well as relatively good stability for both ABV measures (our primary measures of interest), we chose to average each of these metrics across infant age to create average scores for button press ABV, fixation ABV, and attention bias for each caregiver to use in all subsequent analysis. Additionally, due to the onset of the COVID-19 pandemic, this average score mitigated concerns of systematically missing in-person data, as we discussed in the participants section. These ICC metrics also speak to the relative reliability of each ABV measure, and the lack thereof for the traditional dot-probe bias score.

With the relative novelty of both ABV metrics, we then sought to describe the distributions of these metrics within our sample by constructing histograms. Additionally, we assessed interrelations between button press ABV, fixation ABV, and attention bias scores. We also examined interrelations with caregiver anxiety, based on the literature suggesting that ABV and anxiety may be correlated. To mirror our processing of the attention bias metrics, we averaged caregiver anxiety across time points for analytic purposes.

Finally, we used conditional growth models to examine the extent to which infant negative affect systematically varied as a function of age, and the interaction of age with caregiver threat attention metrics (button press ABV, fixation ABV, and attention bias score). Infant age was a continuous variable reflecting the infant's exact age at time of questionnaire completion, and was entered as a random effect in all models. We included child sex, family income, medication usage during pregnancy, infant birthweight, and average caregiver anxiety as conceptually relevant covariates. We also covaried for average number of usable eye-tracking and button press trials, as appropriate.

Participants were included in the analysis if 1) at least one assessment of caregiver dot-probe metric and 2) at least one assessment of infant negative affect was available. Thus, final sample sizes were slightly different for each model.

Models were fitted using the *lme4* package (Bates et al., 2015) in R (R Core Team, 2020). Restricted maximum likelihood (REML) in lme4 was used to handle missing data points in repeated measures of infant negative affect. Statistical significance was evaluated at $\alpha = 0.05$. Significant interactions were probed using simple-slopes and regions of significance analysis using the *interactions* package (Long, 2019).

Results

In examining histograms of each attention bias metric, we noted that both button-press ABV and fixation ABV were positively skewed, but this was not the case for attention bias scores. Histograms can be seen in Figure 3. We also noted that within our sample there were no significant associations between any of our attention bias metrics and caregiver anxiety; the only significant correlation was that between button press ABV and bias score, $b = -0.15$, $p = 0.01$. Full descriptive statistics and correlations are in Tables 2 and 3.

In order to contextualize our findings, we first modeled the prototypical trajectory on infant negative affect over the first 2 years of life, within our sample. A random intercept and slopes linear growth model of infant negative affect indicated that negative affect significantly increased over time, $\gamma_{10} = 0.017$ (SE = 0.003), $p < 0.001$, such that for the prototypical infant, negative affect increased by 0.017, $\gamma_{00} + \gamma_{10} = 2.97 + 0.017 = 2.99$ every month.

Infant negative affect systematically varied as a function of the interaction between infant age and caregiver button press ABV, $\gamma_{50} = -0.0005$, $p < 0.01$ (Table 4). We probed this interaction with regions of significance analyses, shown in Figure 4. For infants whose caregivers demonstrated a low-to-average ABV (<28.03),

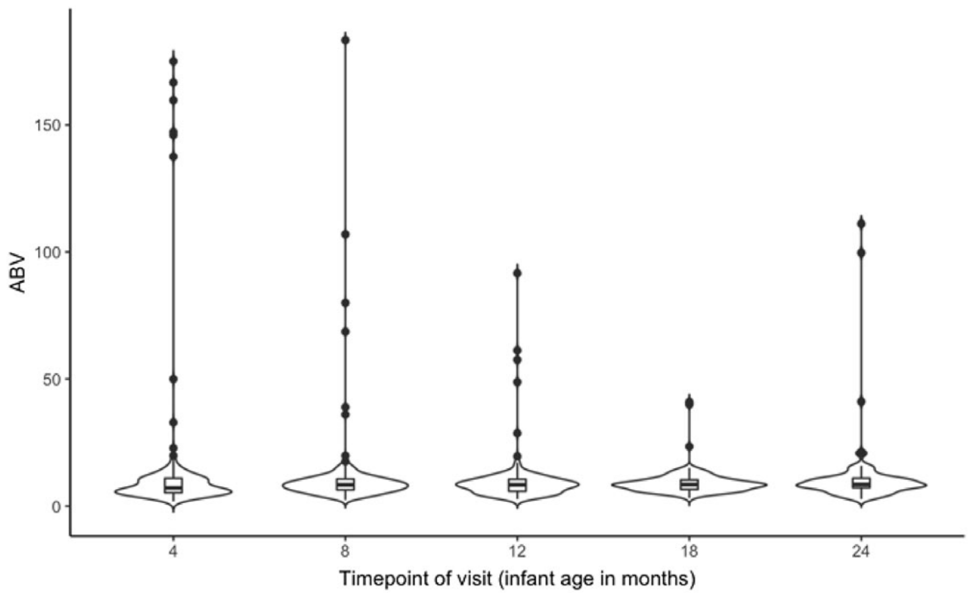

Figure 2. Violin plots depicting the distribution of parent button press ABV across repeated measurements.

infant age was positively associated with negative affect, indicating trajectories that significantly increased between 4 and 24 months. Increases in infant negative affect are in line with the prototypical pattern for the sample, but these increases were potentiated in steepness as caregiver ABV decreased. In contrast, for infants whose caregivers demonstrated a relatively high ABV (>28.03 and <139.26), infant age was not associated with negative affect, indicating that their negative affect trajectories were stable over time. Interestingly, for a small group of infants whose caregivers demonstrated extreme high ABV (>139.26), infant age was negatively associated with negative affect, indicating trajectories that significantly decreased over time.

Infant negative affect trajectories did not systematically vary as a function of caregiver fixation ABV to threat ($p = .56$), threat bias scores ($p = 0.27$), or the interaction between age and either variable ($p = 0.91$ and $p = 0.16$, respectively).

We conducted follow-up analyses to test whether any socioemotional correlates of the COVID pandemic may be driving these results. Tables S1 and S2 in the supplement show this same model run with only children who completed data collection prior to March 11, 2020 ($n = 141$, Table S1) and with children who did not complete data collection prior to this date ($n = 120$, Table S2). We found that the model including the pre-COVID onset sample replicated the directionality and significance of effects as the primary model for button press ABV, indicating that aspects of the COVID pandemic did not drive our reported effects. The model including the post-COVID onset sample retained directionality of effects but the interaction between age and button press ABV did not reach significance.

Discussion

In this study, we assessed the relation between different metrics of caregiver attention and trajectories of infant negative affect over the first 2 years of life. We compared relations between ABV metrics (derived from both button presses and gaze fixations) and the standard threat bias score, which has been traditionally derived from the dot-probe task. Contrary to our hypotheses, high levels of caregiver ABV to threat did not predict steeper positive trajectories of infant negative affect. Instead, we found that very high levels of caregiver ABV to threat related to *decreases* in infant negative affect between 4 and 24 months. We also found that *lower* levels of caregiver ABV to threat, which may reflect more stable attention biases to threat, were related to steeper positive trajectories of infant negative affect over time. These changes in negative affect through development reflect changes in how an infant/toddler is responding to stimuli in their environment that they may find unpleasant, frightening, or frustrating (Gartstein & Marmion, 2008). Interestingly, these findings were specific to ABV to threat derived from button presses, while no significant effects emerged for ABV to threat derived from fixation data or for traditional threat bias scores.

These findings suggest that ABV to threat from button presses, ABV to threat from gaze fixations, and threat bias scores may capture distinct attentional mechanisms. Outside of a correlation between button press ABV and traditional bias scores, these metrics were not correlated and had different distributions. Prior work suggests that ABV to threat derived from button press captures regulatory behaviors such as emotion regulation (Bardeen et al., 2017; Klanecky Earl et al., 2020) and/or attentional control (Bardeen et al., 2016; Clarke et al., 2020), especially when presenting threat-valenced stimuli. In this context, high ABV would reflect low emotion regulation and/or attentional control and low ABV reflects high emotion regulation and/or attentional control.

Differences in a caregiver's responses to their infant cues and their immediate environment may uniquely impact the quality of caregiver–infant interactions. For example, caregivers with higher attentional control may more readily anticipate and attend to infant emotional cues, facilitating the caregiver's accurate interpretation of infant negative affect in context to consistently respond with sensitive behaviors. Although empirical work on the specific relation between visual attention and parenting behaviors is scarce, findings from studies of parental self-regulation support this interpretation. For example, higher maternal self-regulation has been associated with lower infant negative affect (Bridgett et al., 2013), and parents with higher effortful control and executive function are more likely to respond in a nonnegative way to children's negative cues (Geeraerts et al., 2021).

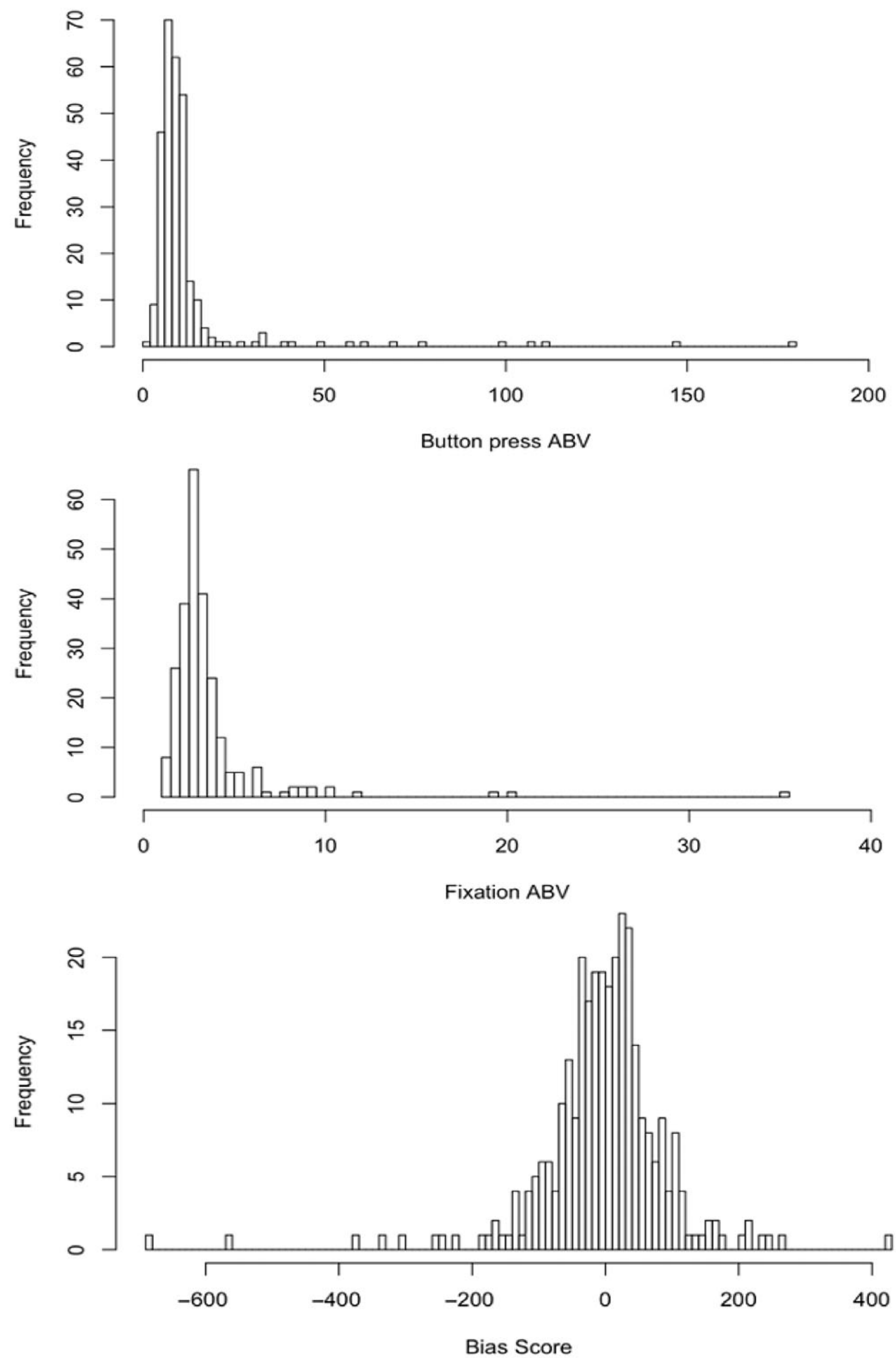

Figure 3. Histograms depicting distributions of each attention bias metric within the sample. Note that axis scales are different across plots.

While the direction of our effects seems to contradict these previous findings, other studies of parenting and temperament suggest that some parenting behaviors associated with high attentional control in caregivers are not necessarily adaptive for all children. For example, Kiel and Buss (2010) reported that for temperamentally fearful children, mothers' ready anticipation of children's fearful responses was associated with the perpetuation of high fear. Furthermore, in a follow-up study of the same fearful children, they also reported that higher maternal accuracy in predicting children's fear responses at age two predicted greater social withdrawal at age five (Kiel & Buss, 2011). Indeed, the association between caregiver ABV and significant increases in infant negative affect only emerged in our sample at low-to-average levels of ABV, which at the extreme may indicate extremely high attentional control on the part of the caregiver.

Borrowing from the attention literature more broadly, recent work also suggests that extreme high attentional control may reflect *over*control and rigid cognitions that may confer risk for

Table 2. Descriptive statistics for attention bias metrics collected from the caregiver, in addition to caregiver anxiety and repeated measures of infant negative affect

Measure	*M*	*SD*	Range
1. Button press ABV	12.26	18.12	1.88–179.17
2. Fixation ABV	3.48	2.98	1.09–35.00
3. Bias score	−3.18	98.75	−681.12–421.31
4. Average Anxiety	6.31	6.63	0–44.33
5. 4 m Negative Affect	2.97	0.62	1.34–5.08
6. 8 m Negative Affect	3.13	0.69	1.54–5.13
7. 12 m Negative Affect	3.27	0.66	1.00–5.00
8. 18 m Negative Affect	3.29	0.66	1.71–5.29
9. 24 m Negative Affect	3.33	0.70	2.00–5.61

psychopathology in the individual. Specifically, rigidity in attention may potentiate periods of negative affect and inability to disengage from negative states, which over time may potentiate risk for internalizing disorders (Gilbert et al., 2020; Henderson et al., 2015; Henderson & Wilson, 2017; White et al., 2011). Therefore, it is possible that low ABV may play a role in anticipatory and overprotective behaviors, which as reported by Kiel and Buss (2010, 2011), may then lead to potentiated increases in infant negative affect over time. Low ABV can also be interpreted as reflecting the stability/consistency of a caregiver's attentional bias to or away from threat, which may similarly relate to the way that they curate or filter their infant's socioemotional environment and have implications for levels of infant negative affect over time (Vallorani et al., 2021).

We were surprised to find that high caregiver ABV to threat related to decreases in negative affect. Typically, we see normative increases in negative affect through infancy (Braungart-Rieker et al., 2010; Dollar & Calkins, 2019), as was the case in our overall sample. This increase in negative affect reflects, in part, the infant's growing awareness of their own motivations and goals, the limitations imposed by the environment and their own immaturity, and the resulting feelings of frustration and distress (Dollar & Calkins, 2019).

Although relatively little work has sought to interpret what decreases in negative affect may mean in infant emotional development, we put forward the idea that this trajectory may reflect the infant's response to diminished environmental responsiveness. However, we acknowledge that the regions of significance analysis found that decreases in negative affect were significant only for extremely high levels of caregiver ABV, specifically levels greater than 10 standard deviations above the mean, so these patterns may reflect a small subsection of the general population. As reviewed, high ABV may relate to a caregiver's low attentional control and/or emotion regulation. These behaviors may manifest in the way that a caregiver curates their household and/or interacts with their infant. If a caregiver is low in attentional control or emotion regulation, they may be disorganized in the way they manage their household or inconsistent in the way that they respond to their child. With repetition, a lack of statistical regularity in an infant's environment may alter the threshold at which they respond to environmental stimuli, or the nature of these responses (Sherman et al., 2020).

Another possible explanation is that parents with extreme patterns of ABV may interpret their infants' behaviors differently than parents with more moderate levels of ABV, and these differences are reflected in caregiver reports of infant temperament. Future work should examine interrelations between levels of caregiver ABV and more naturalistic parenting behaviors, parent–child interactions, and/or infant temperament to directly test each of these possible explanations.

Our study provides preliminary evidence that *extreme* patterns of ABV to threat, not just high ABV, may contribute to socioemotional development. For example, it may be that either the unpredictability posed by high ABV to threat or the rigidity posed by low ABV both evoke adaptation in infants to cope with potentially extreme rearing environments, and that these compensatory mechanisms are reflected in their trajectories of negative affect. While some increases in negative affect over time are normative (Braungart-Rieker et al., 2010; Dollar & Calkins, 2019), more work is also needed to investigate the threshold at which increases in negative affect trajectories predict maladaptation. Similarly, there is a paucity of work examining the implications of decreases in negative affect over time. As such, additional research should interrogate how these early life trajectories are associated with socioemotional development.

These data add to the literature that characterizes ABV to threat within a community sample. While most work with ABV has been focused on clinical populations, such as individuals with PTSD (Badura-Brack et al., 2015; Bardeen et al., 2016; Iacoviello et al., 2014; Naim et al., 2015; Swick & Ashley. 2017), the current sample was relatively racially and socioeconomically diverse, and not strategically selected for psychopathology. Indeed, within our sample only 4 caregivers had an average anxiety score suggesting "severe" anxiety (1.38%), and only 25 caregivers had an average anxiety score suggesting anxiety of "moderate" levels (8.65%) (Beck & Steer, 1993). Participants provided up to five repeated measures of ABV over the course of nearly 2 years, as well as traditional threat bias scores from the dot probe and ABV derived from gaze fixation data. Here, we found that these metrics were all relatively stable over time, suggesting that ABV to threat may be trait-like during adulthood among a generally healthy sample. ICC values for button press ABV, fixation ABV, and traditional bias scores also revealed that both ABV metrics offered relatively good reliability, where bias scores had low reliability. This is consistent with previous work examining psychometrics of the dot-probe task (Chapman et al., 2019; Price et al., 2015; Schmukle, 2005).

Additionally, the caregivers in this sample were all postpartum, and the time after childbirth is often associated with fluctuations in depression, anxiety, and stress for parents (Matthey et al., 2003; Pawluski et al., 2017). And yet, we did not note fluctuations in ABV or attention bias. However, we offer the caveat that we do not have data on ABV prior to childbirth, so we cannot speak to stability across both prenatal and postnatal years. We also note that within this sample, we found no significant associations between anxiety and button press ABV, fixation ABV, or a traditional threat bias score.

We also found that ABV to threat derived from button presses had a different relation to longitudinal changes in infant negative affect than ABV to threat derived from gaze fixations, as well as traditional dot-probe threat bias scores. This suggests the uniqueness of button press ABV in capturing cognitive processes within an emotional context. This dissociation between button press

Table 3. Correlations between attention bias metrics collected from the caregiver, in addition to caregiver anxiety and repeated measures of infant negative affect

Measure	1.	2.	3.	4.	5.	6.	7.	8.
1. Button press ABV								
2. Fixation ABV	0.07							
3. Bias score	−0.15*	−0.05						
4. Average Anxiety	−0.01	0.04	0.01					
5. 4 m Negative Affect	0.08	0.05	−0.09	0.12				
6. 8 m Negative Affect	−0.02	0.04	0.03	0.15*	0.68***			
7. 12 m Negative Affect	−0.09	0.10	0.01	0.15*	0.51***	0.66***		
8. 18 m Negative Affect	−0.07	0.01	−0.14	0.09	0.50***	0.44***	0.49***	
9. 24 m Negative Affect	−0.14	0.08	0.00	0.16*	0.38***	0.53***	0.58***	0.66***

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

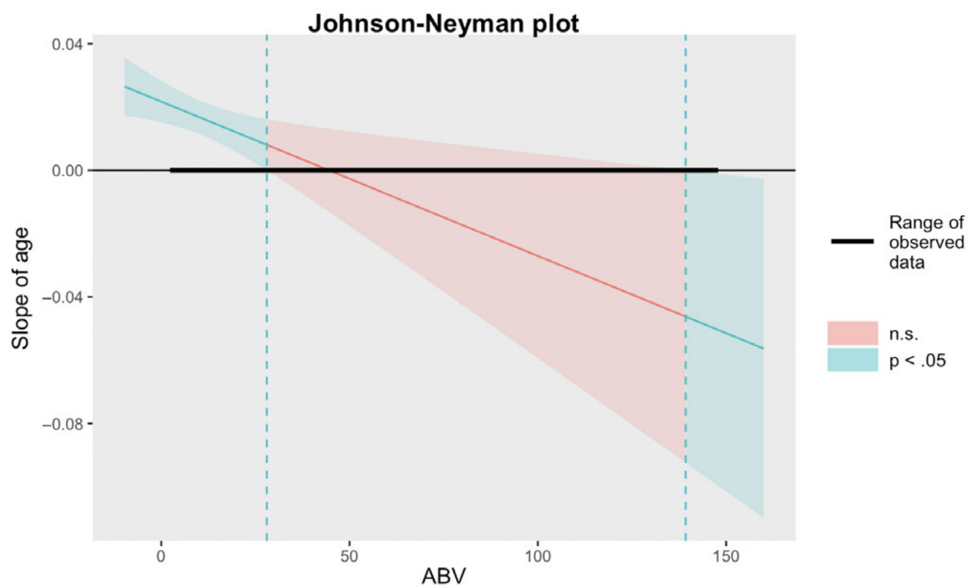

Figure 4. Johnson–Neyman plot showing regions of significance for the two-way interaction between caregiver button press ABV to threat and infant age on infant negative affect.

metrics and eye-tracking metrics is not unusual (e.g., Fu et al., 2019). This may be in part due to the fact that eye-tracking is a more proximal metric of attention, while reaction time is often an endpoint in a cascading set of processes such as perceptual processing, decision-making, and, finally, initiating a motor response. Thus, our data suggest that the processes associated with infant trajectories of negative affect may emerge within this cascade, and after initial patterns of visual attention, which may be more reflexive.

While more work is needed to better understand the more specific cognitive processes underlying differences in ABV to better characterize the metric, these findings give further credence to the notion of including ABV as a metric in studies involving the dot probe as an additional way of capturing individual differences in attention to affective cues. Bivariate correlations also found that button press ABV was significantly, inversely related to bias scores. Very limited work has examined button press ABV and vias scores within the same sample to date; future work should both seek to replicate this finding as well as better test possible mechanisms underlying this relation. Future work should also continue to examine ABV in community samples and better understand relations between ABV and attentional control and/or emotion regulation.

This study is not without its limitations. We note that ABV and report of infant negative affect were provided by the same individual, which may bias results. For example, caregiver ABV may relate to underlying biases that the caregiver has in assessing their infant's behavior. Thus, with our current analysis it is possible that it is not the infant's negative affect is decreasing over time, but that the parent's perception of their infant's negative affect is changing over time. However, recent work suggests that mothers can disaggregate self-report of child temperament from their own symptom profile (Olino et al., 2020). Future work should incorporate parent-report of infant negative affect from multiple caregivers, as well as behavioral assessments of temperament to examine how caregiver ABV relates to longitudinal changes in these metrics over time.

In conclusion, these data suggest that caregiver ABV to threat may be a relevant factor in an infant's ecosystem, with potential

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Table 4. Multilevel model assessing relations between button press ABV and infant age on infant negative affect, covarying for child sex, family income, medication usage during pregnancy, and infant birthweight

Parameter	*Estimate*	*SE*	*t-value*
Fixed effects			
Intercept	2.86***	0.09	33.62
Child sex	0.02	0.07	0.23
Family income	−0.05**	0.02	−2.73
Medication during pregnancy	0.03	0.07	0.43
Infant birthweight	−0.01	0.03	−0.17
Mean number of usable trials	<0.01	<0.01	0.51
Caregiver average anxiety	0.01*	0.01	1.99
Child age	0.02***	<0.01	6.48
Button press ABV	0.01	<0.01	1.35
Age × Button press ABV	<−0.01**	<0.01	−2.68
Random effects			
Intercept	0.57		
Age	0.03		
Residual	0.38		

Note: Model based on 893 repeated measures of infant negative affect, nested within 239 persons.
Child sex: 1 = male, 2 = female
Family income, birth weight, mean number of usable trials, and caregiver average anxiety were mean centered
$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

influences on how levels of infant negative affect change over the first 2 years of life. Additionally, our findings pose the idea that both high *and* low caregiver ABV to threat may be a potential risk factor in infant trajectories of negative affect within the caregiver–child dyad. Additional work is needed to support the emerging idea that caregiver affect-biased attention is an important contextual influence on infant socioemotional development.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0954579422000736

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Conflicts of interest. None.

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