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ABSTRACT

Anxiety disorders affect approximately one third of children and adults in the United States, causing a significant burden to the individual and society. Attention bias towards threat is the tendency to systematically attend to threatening cues in the environment and it may play a crucial role in the emergence and maintenance of anxiety. A growing number of studies suggest that individuals with high trait or clinical anxiety show a heightened attention bias to threat, making it an important marker of anxiety. Moreover, experimental interventions have found that manipulating the levels of attention bias consequently reduced levels of anxiety and sensitivity to stress, suggesting that such interventions could be used for preventive or therapeutic purposes. However, recent studies have reported mixed findings. This inconsistency complicates the interpretation of attention bias to threat as a marker of anxiety, as well as its potential as an effective intervention. Importantly, this variability in the findings is not considered to represent “noise,” but meaningful individual differences in how anxiety and attention bias manifest. The goal of the current dissertation was to better characterize these individual differences. This goal was accomplished by performing three separate studies that together addressed two outstanding issues of the current attention bias literature.

The first was to study attention bias and its relation to anxiety from a developmental approach as most empirical investigations and theoretical models of attention bias lack a developmental perspective. The other major outstanding issue in the current attention bias literature is that the mechanisms behind attention bias are not well understood. The present dissertation investigated the mechanisms of attention bias by using several methods. Specifically, these studies employed multiple attention bias tasks, measured eye movement, assessed neural correlates, and evaluated the impact of a theoretically relevant cognitive process (i.e., effortful control).

The results from the current dissertation suggest that: 1) it is important to consider cross-task attention bias convergence as this may index important individual characteristics such as fearful temperament and/or anxiety; 2) Attention bias can be captured during infancy and that meaningful individual differences in attention bias exist from early in development such as relations with known risk factors for anxiety; 3) other cognitive functions like effortful control likely play an important role in the relations between attention bias, fearful temperament, and anxiety. More specifically, that in early childhood, effortful control likely serves as a protective factor rather than a risk factor. Implications of these findings, limitations, as well as future directions are discussed in this dissertation.
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Chapter 1

General Introduction

Attention bias towards threat, the tendency to systematically attend to threatening cues in the environment, has received considerable attention for its putative role in the acquisition and maintenance of anxiety. A growing corpus of studies suggests that individuals with high trait or clinical anxiety show an attention bias (AB) to threat (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). This bias is pervasive across anxiety disorders: evident in children and adults, across anxiety diagnoses, and among individuals with clinical anxiety as well as high trait anxiety (Bar-Haim et al., 2007), making it an important marker for the disorder. A direct extension of these findings has been the development of interventions aimed to reduce anxiety by manipulating the level of bias (through Attention Bias Modification Training; ABMT). Initial investigations showed great promise, as modulating AB subsequently reduced levels of anxiety and sensitivity to stress (Hakamata et al., 2010; MacLeod & Clarke, 2015), suggesting that AB to threat may play a causal role in the emergence of anxiety (Van Bockstaele et al., 2014).

However, recent studies have reported mixed findings, with multiple studies failing to find the expected relations (Britton et al., 2012, 2013; Gotlib et al., 2004; Pineles & Mineka, 2005; Pishyar, Harris, & Menzies, 2004; Waters, Lipp, & Spence, 2004) and other studies finding the opposite patterns of results (i.e., anxiety-linked attentional avoidance or bias away from threat) (Brown et al., 2013; Mansell, Clark,
In addition, although many studies find apparent positive effects for ABMT (Bar-Haim, 2010; Hakamata et al., 2010; MacLeod & Clarke, 2015), others do not find a significant change in bias or a reduction in anxiety symptoms (Heeren, Mogoșe, Philippot, & McNally, 2015). This inconsistency complicates the interpretation of AB to threat as a marker of anxiety, as well as its potential as a therapeutic intervention. Importantly, this variability in the findings is not thought to represent “noise,” but meaningful individual differences in how anxiety and AB manifest (Roy, Dennis, & Warner, 2015). The present dissertation aims to better characterize these individual differences by expanding on several outstanding issues of the current AB literature. These issues include:

1) **Lack of a developmental focus.** Most of the theoretical models concerning AB and its relation to anxiety lack a developmental perspective (Field & Lester, 2010a). This greatly limits our knowledge of the causes and emergence of AB. Vulnerability for anxiety has roots early in development (Pine, 1998; Pine & Fox, 2015) and thus young children may present critical targets for preventive intervention. The optimal way to answer these questions would be to perform longitudinal studies assessing AB and its relation to anxiety over time. These studies are now emerging (e.g., White et al., 2017), but they require a considerable amount of time and resources. One way to begin informing the development of AB is to perform studies in children, at various ages, and in populations at risk for anxiety. Research in developmental psychology has identified temperamental fear (e.g., behavioral inhibition; Buss, 2011; Clauss &
Blackford, 2012; Kagan & Fox, 2006; Pérez-Edgar & Fox, 2005b) and maternal anxiety (Merikangas, 2005), as strong early predictors of later anxiety. These established early risk factors for anxiety are good initial candidates to explore the development of AB and anxiety.

2) **The mechanisms behind AB are poorly understood.** Attention bias is most often measured with one task, the dot probe task (Roy et al., 2015). Moreover, a variation of the task (i.e., ABMT) has been proposed as a therapeutic intervention for anxiety, with promising initial results. For instance, MacLeod and colleagues (2002) found that changing the contingency of where the probe appears (e.g., mostly appearing behind the neutral face as opposed to behind the angry face) reduced bias towards threat and negative affect in response to an experimental stressor. Similar findings have been documented in individuals with clinical anxiety, suggesting a causal role for attention bias in the emergence and perpetuation of anxiety (Hakamata et al., 2010; Linetzky, Pergamin-Hight, Pine, & Bar-Haim, 2015).

While the wide adoption of the dot probe task greatly aids in cross-study comparisons, it is possible that using a single task is not sufficient to evaluate the impact of AB on anxiety. In this task, individuals briefly see two competing stimuli (one neutral and one emotional) and then respond to a probe that appears in the same location as one of the stimuli. An AB towards emotional stimuli is present when participants preferentially attend to emotional cues, marked by decreased reaction times (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. This inference assumes that RTs provide an accurate measure of attention allocation (Harrison & Gibb, 2014). Even if this assumption were correct, RTs measures cannot track the pattern of attention across a trial, reducing all contributing processes to a single number. That is, individual differences in cue processing, cue disengagement, response speed, and competing approach/avoidance mechanisms may all be in play (Mogg, Holmes, Garner, & Bradley, 2008). This blurring of multiple processes can obscure any true signal of bias, leading to the inconsistent findings observed in the literature. The following approaches would further our understanding of the mechanisms behind AB:

a. Employing multiple tasks that capture multiple facets of AB may help better characterize attention and evaluate which patterns of AB across tasks are most predictive of risk.

b. Measuring eye movements during AB tasks would allow us to evaluate at what stage of the attentional process (e.g., orienting/facilitated attention or disengagement) an anxiety-related bias occurs.

c. Measuring electroencephalogram (EEG) signals during the task would provide information about the neural mechanisms that underlie AB, particularly by evaluating the relation of event-related potential (ERP) components to AB and anxiety and the chronometry of the underlying processes.
d. Assessing the impact of other theoretically relevant cognitive processes (e.g., effortful control) on AB would evaluate if and how associated processes moderate or mediate the effects of AB.

The present dissertation is a set of three studies designed to expand our knowledge of the development of AB and its relation to anxiety, as well as the mechanisms that may underlie this relation. Each of the studies is at a different stage of the publication process. In the first study (Morales, Taber-Thomas, & Pérez-Edgar, 2016), we examine patterns of AB across two related measures in a sample of 114 9-12 year olds. In addition, we test if the relation among AB measures varies across BI and if specific patterns of attention across tasks are associated with anxiety. In this study, we first tested the relation between BI, anxiety, and AB towards threat for each task separately. We hypothesized that BI children would display a larger bias towards threat in both tasks. Second, we tested the relation between the two tasks and then looked to see if the relation varied by BI status. We hypothesized that bias patterns would be related, particularly in BI individuals since they are at increased risk for anxiety. Third, we explored the possibility that convergent patterns of AB across the two tasks were related to anxiety levels. Finally, we examined if the relation between patterns of attention in the tasks and anxiety differs by BI status.

In the second study (Morales, Brown, Taber-Thomas, Buss, & Pérez-Edgar, 2017), we measure AB by examining eye movements in 98 infants ages 4 to 24 months of age during a task that disengagement from emotional stimuli. We investigate if AB towards threat is associated with known risk factors for anxiety, such as maternal anxiety and fearful temperament. Importantly, we examine these relations during the
developmental period when AB is thought to emerge. We hypothesize that: A) there will be an attentional bias towards threat in the full sample of infants, replicating previous studies (e.g., Peltola et al., 2008), B) attentional bias towards threat will be positively related to maternal anxiety, and C) attention bias towards threat will be positively related to fearful temperament. Finally, D) we explore the potential interaction between fearful temperament and maternal anxiety in predicting attention bias towards threat.

Finally, in the third study we evaluate the relation between effortful control and attention bias in children ages 5 to 6 years. It has been proposed that self-regulatory factors such as effortful control moderate the relation between fearful temperament and AB (Lonigan, Vasey, Phillips, & Hazen, 2004). It is possible that fearful children with high levels of effortful control are able to better regulate their attention and override their initial bias. Thus, they would not display an AB to threat. In line with this assumption, we expected that the relation between AB and fearful temperament will be moderated by effortful control, such that an AB will be displayed only for highly fearful children with low effortful control (Lonigan et al., 2004). Secondly, we examined the relation between AB and behavioral measures of effortful control. In line with Henderson et al. (2015), in which higher effortful control is related to fearful temperament and increased risk for anxiety, we expected higher effortful control in highly fearful children. We also explored the potential role of behavioral measures of effortful control as moderators or mediators of the link between fearful temperament and AB. We also examined the relation between AB, fearful temperament, and neural (i.e., ERP) markers of effortful control. We explored if these control-related ERP markers moderate or mediate the relation between
AB and fearful temperament. Finally, we examined if the different measures of effortful control moderated or mediated the relation between temperament and anxiety.

Overall, these three studies improve our understanding of AB by taking a developmental approach and exploring the mechanism behind AB. The specific contribution of each study to the issues outlined is summarized in Table 1.

Table 1-1: Contributions of each study to the issues outlined.

<table>
<thead>
<tr>
<th>Study</th>
<th>Developmental Focus</th>
<th>Mechanisms behind AB</th>
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<td>Risk for Anxiety</td>
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All three studies provide information regarding the development of AB and anxiety. In all studies we take a developmental psychopathology approach by studying children and infants at risk for anxiety. In addition, the studies proposed contribute to our understanding of the mechanism behind AB. Study 1 utilizes multiple tasks to capture patterns of AB across tasks. Study 2 uses eye tracking measures to evaluate AB in infancy, capitalizing on the fact that eye tracking methods do not require a behavioral response. Study 3 evaluates the role of another cognitive process (i.e., effortful control) and its related neural markers in the relation between fearful temperament and attention bias. Together, the proposed dissertation aims to improve our characterization of individual differences in attentional patterns that are predictive of anxiety by taking a developmental and multi-method approach to try to elucidate some of its underlying mechanisms.
The following sections provide a detailed description of each study in their current state. Each study is meant to be a stand-alone journal article. Thus, some sections may be repetitive relative to the introduction and across each study.
Chapter 2

Study 1: Patterns of Attention to Threat across Tasks in Behaviorally Inhibited Children at Risk for Anxiety.

Authors: Santiago Morales, Bradley C. Taber-Thomas, and Koraly E. Pérez-Edgar


Abstract

Although attention bias towards threat has been causally implicated in the development and maintenance of fear and anxiety, the expected associations do not appear consistently. Reliance on a single task to capture attention bias, in this case overwhelmingly the dot-probe task, may contribute to this inconsistency. Comparing across attentional bias measures could help capture patterns of behavior that have implications for anxiety. This study examines the patterns of attentional bias across two related measures in a sample of children at temperamental risk for anxiety. Children (Mean age=10.19±0.96) characterized as behaviorally inhibited (N=50) or non-inhibited (N=64) via parent-report completed the dot-probe and affective Posner tasks to measure attentional bias to threat. Parent-report diagnostic interviews assessed children’s social anxiety. Behavioral inhibition was not associated with performance in the dot-probe task, but was associated with increased attentional bias to threat in the affective Posner task. Cross-task convergence was dependent on temperament, such that attention bias across the two tasks was only related in behaviorally inhibited children. Finally, children who
were consistently biased across tasks (showing high or low attentional bias scores in both
tasks, rather than high in one but low in the other) had higher levels of anxiety.
Convergence across attention bias measures may be dependent on individuals’
predispositions (e.g., temperament). Moreover, convergence of attention bias across
measures may be a stronger marker of information processing patterns that shape
socioemotional outcomes than performance in a single task.

**Introduction**

A growing literature base suggests that individuals with high trait or clinical
anxiety levels show an attention bias (AB) to threat (Bar-Haim et al., 2007). This bias is
evident in children and adults across diagnoses (Bar-Haim et al., 2007), and manipulating
the level of bias (through AB Modification) appears to modulate anxiety levels
(Hakamata et al., 2010; MacLeod & Clarke, 2015). As a result, many suggest that AB to
threat plays a causal role in the emergence of anxiety (Van Bockstaele et al., 2014). Yet,
there is a good deal of inconsistency in the literature as some data point to anxiety-linked
attention avoidance (Brown et al., 2013; Mansell et al., 1999; Morales, Pérez-Edgar, &
Buss, 2014; Salum et al., 2013; Stirling et al., 2006; Waters et al., 2014) and other data
show null findings when comparing anxious/at-risk participants against healthy controls
(Pérez-Edgar et al., 2011; Waters et al., 2004). These mixed findings may be due to AB
being measured overwhelmingly with one task—the dot-probe task. If AB acts as a trait-
level mechanism, we would expect a bias to appear at multiple points in the attentional
system and exhibit consistency across contexts. The dot-probe task by itself may be
insufficiently sensitive to fully capture the biases in attention that influence social anxiety.

Few studies have examined potential convergence among AB measures, which would perhaps better capture the atypical threat load on the attentional system associated with anxiety. It may be that some individuals consistently show a bias to threat, while others display a bias on only a subset of measures. Indeed, individuals may be at highest risk when they exhibit consistent AB across multiple measures, reflecting stable or entrenched processing patterns and removing the “noise” of specific task parameters. The present study evaluates the relations across two AB tasks and their concordant impact on anxiety in a sample of children at temperamental risk for anxiety.

Behavioral Inhibition (BI) is an early emerging temperamental type marked by high fear towards novelty and social reticence (N. A. Fox, Henderson, Marshall, Nichols, & Ghera, 2005). Children who exhibit stable BI are at increased risk for anxiety during adolescence, particularly social anxiety (Chronis-Tuscano et al., 2009), making it one of the best early predictors of anxiety. However, not all children classified as BI display inhibition at later ages and only ~40% go on to develop anxiety problems (Clauss & Blackford, 2012). Intervention efforts need to identify the factors that moderate the stability of BI, as well as the association between early BI and anxiety. One such factor is AB towards threat.

Studies examining AB in BI have been sparse with mixed results. Adolescents characterized as BI in childhood exhibited a larger bias towards threat in adolescence versus non-BI (BN) peers (Pérez-Edgar et al., 2010), while no AB difference was found at age 5 between BI and BN children (Pérez-Edgar et al., 2011). This young sample also
failed to show group differences when AB to threat was measured again at age 7 (White et al., 2017). However, in all three studies, AB moderated the relation between BI and anxiety-related outcomes. Specifically, BI children continued to display inhibited behavior in childhood and adolescence only if they also displayed AB towards threat. Similarly, early BI only predicted anxiety later in childhood for children who exhibited a bias towards threat.

The existing evidence suggests that AB towards threat is an important developmental tether impacting broad information processing patterns such that this bias impacts their interpretation of, memory for, and response to the environment, keeping them at risk for anxiety across development (Pérez-Edgar, Taber-Thomas, Auday, & Morales, 2014). However, it is unclear if there are stable group-level differences in AB between BI and BN children. The broader AB to threat literature presents a similar scenario, as several studies do not find group differences between anxious and non-anxious participants (Waters et al., 2004), while other studies find that anxious individuals (Brown et al., 2013; Mansell et al., 1999; Salum et al., 2013; Stirling et al., 2006; Waters et al., 2014), as well as individuals at temperamental risk for anxiety (Morales et al., 2014), display AB away from threat.

The AB literature is heavily based on the dot-probe task (Todd, Cunningham, Anderson, & Thompson, 2012). 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 AB towards emotional stimuli is present when participants preferentially attend to emotional cues, marked by decreased reaction times (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. While its wide adoption greatly aids in cross-study comparisons, it is possible that using a single task is not sufficient to evaluate the impact of AB on anxiety. Attention bias may emerge from different stages of the attentional process. Comparisons across domains and/or employing multiple tasks that capture multiple facets of AB may help better characterize attention and evaluate which patterns of AB across tasks are most predictive of risk. The present study focuses on the latter, relying on two widely used measures as an initial examination.

The few studies that have compared the dot-probe task to other measures of AB have found no relation between tasks (Broeren, Muris, Bouwmeester, Field, & Voerman, 2011; Brown et al., 2014; Dalgleish et al., 2003). However, the tasks were often dissimilar in scope (e.g., the dot-probe task using faces vs. the emotional Stroop task using words; Dalgleish et al., 2003). In addition, it is possible that convergence in AB is observed only in individuals at highest risk for, or with the highest levels of, anxiety. In this way, the convergence of AB across tasks may itself be a meaningful individual difference variable.

Several tasks have been used to measure AB (see Van Bockstaele et al., 2014). The Posner task (or attentional cueing task) is the most similar to the dot-probe task. In the Posner task (Posner, 1980), a single cue briefly appears on one side of the visual field (left or right). Following cue removal, a target probe appears either in the same location as the cue (valid trials) or on the opposite side of the cue (invalid trials). The validity score is the RT on invalid trials minus valid trials. This difference (the validity effect) is
believed to represent the effort required to disengage from invalid cues. In the affective Posner task, the cues have an emotional valence based on punishment and reward cues, emotional words, or emotional facial expressions (Derryberry & Reed, 2002; E. Fox, Russo, Bowles, & Dutton, 2001; Pérez-Edgar, Fox, Cohn, & Kovacs, 2006; Van Damme & Crombez, 2009).

Anxious individuals have greater difficulty with attention disengagement (larger validity effects) in the affective Posner task (Cisler & Olatunji, 2010; Derryberry & Reed, 2002; E. Fox, Russo, Bowles, & Dutton, 2001). In the only affective Posner task study with BI, children completed the task under neutral and affectively charged conditions (Pérez-Edgar & Fox, 2005a). BI children exhibited a larger validity effect, larger event-related potentials, and greater right electroencephalogram asymmetry compared to BN children only under the affective condition.

The current study examined the association between AB to threat as measured by the dot-probe and affective Posner tasks in BI and BN children. First, we tested the relation between BI, anxiety, and AB towards threat for each task separately. We hypothesized that BI children would display a larger bias towards threat in both tasks. Second, we tested the relation between the two tasks and then looked to see if the relation varied by BI status. We hypothesized that bias patterns would be related, particularly in BI individuals since they are at increased risk for anxiety. Third, we explored the possibility that convergent patterns of AB across the two tasks were related to anxiety levels. Finally, we examined if the relation between patterns of attention in the tasks and anxiety differs by BI status.
Method

Participants

The sample consisted of 114 9-12 year olds (55 boys; Mean\_age=10.19; SD=0.96). Families were recruited through a university database of families interested in participating in research studies, community outreach, and word-of-mouth. As part of a larger study on temperament, attention, and anxiety, the tasks were typically completed on separate testing days (97%, Mean\_gap=6 days). Participants were screened using parental report on the Behavioral Inhibition Questionnaire (BIQ; Bishop, Spence, & McDonald, 2003). Children who met BI cutoff scores (>120 in BIQ Total score or >60 in BIQ Social novelty; ~25% of children screened) were identified and oversampled (N=50), while children below cutoff were recruited as a gender- and age-matched non-BI comparison group (N=64; not yoked). Our cut-off scores were based on previous studies of extreme temperament in children (Broeren & Muris, 2010). The sample was 69.3% Caucasian, 1.8% African American, 5.3% biracial, 1.8% other ethnicities, and 21.9% did not answer. Exclusionary criteria included severe psychiatric diagnosis (e.g., bipolar disorder), IQ below 70, or severe medical illness. Parents and children provided written consent/assent and the Institutional Review Board approved this study.

Children were excluded due to being a member of a sibling pair participating in the study (N=3) or poor performance (<75% accuracy) in the dot-probe (N=14) or affective Posner (N=2) tasks. The 93 children with data for cross-task analyses did not differ from the rest of the sample in any of the study measures, t’s<1.24, p’s>.27, d’s<.64.
Measures

**Behavioral Inhibition** was assessed using the BIQ (Bishop et al., 2003), a 30-item measure assessing the frequency of BI-linked behavior in the domains of social and situational novelty on a seven-point scale from 1 (“hardly ever”) to 7 (“almost always”). The questionnaire has adequate internal consistency and validity in differentiating BI from BN children (Bishop et al., 2003) and parent-reports on the BIQ correlate with laboratory observations of BI (Dyson, Klein, Olino, Dougherty, & Durbin, 2011). The BIQ had good internal consistency in the current study ($\alpha=.91$).

**Social Anxiety Symptoms** were assessed via parent report on the computerized Diagnostic Interview Schedule for Children version 4 (C-DISC 4; Shaffer, Fisher, Lucas, Dulcan, & Schwab-Stone, 2000). A trained research assistant conducted the semi-structured interview, in which parents judged DSM-IV symptoms as either present (“yes”) or absent (“no”). A continuous measure of endorsed symptoms (symptom count) was used in this study.

**AB to Threat** was measured via the dot-probe and affective Posner tasks. We removed incorrect trials, trials with RTs of less than 150ms or more than 2000ms, and trials with RTs +/- 2 SDs from an individual’s mean before analyses.

**Dot-probe task.** Each trial began with a 500ms fixation, followed by a face pair displayed above and below the fixation point (500ms). The faces were replaced by an arrow-probe presented (1000ms) in the location of one of the faces. Children indicated as quickly and accurately as possible whether the arrow pointed left or right via button press (response recorded for 2500ms). The visual angle for the face stimulus was
5.3°(H)*6.2°(V). Inter-trial intervals varied between 250ms to 750ms (average 500ms).

Face pairs of 10 actors (5 female; NimStim, Tottenham et al., 2009) were displayed across 240 trials divided into two runs with 80 trials per condition: congruent trials, in which the angry-neutral face pair was followed by an arrow in the same position as the angry face; incongruent trials, in which the probe appeared on the opposite side of the angry face; and neutral-neutral trials, with the probe in either location. AB scores to angry faces were calculated as mean RT for incongruent trials minus mean RT for congruent trials. Positive values indicate a bias towards threat whereas negative values indicate bias away from threat.

_Affective Posner task._ Each trial began with a 500ms fixation, followed by a single face presented on the middle, left, or right of the fixation (500ms). The faces were replaced by a white square (1000ms) in either the left or right face location. Participants indicated as quickly and accurately as possible the location of the square via button press (response recorded for 2500ms). The visual angle for the face stimulus was 3.8°(H)*4.7°(V). The inter-trial interval was 500ms.

The same face pairs were used in both tasks. There were on average 33 trials per condition: angry valid trials, in which the angry face was followed by a square in the same spatial location; angry invalid trials, in which the angry face was replaced by a square on the opposite location; and angry middle trials, in which the angry face appeared on the middle of the screen (fixation probe location) followed by a square on either side (left or right). Neutral valid, invalid, and middle trials were identical, but with a neutral face serving as the cue rather than an angry face. Middle trials served as controls and catch trials. The validity score was calculated as the average RT to targets in invalid trials.
minus the average RT to targets in valid trials for angry and neutral cues separately. This generated an angry validity score and a neutral validity score; positive values represent the effort to disengage from the cue in invalid trials.

**Statistical Analyses**

To test for differences in the dot-probe task, an independent samples *t*-test examined the effect of BI status (BI vs. BN) on AB. One-sample *t*-tests versus zero were used to separately assess group patterns of AB. For the affective Posner task, a 2x2x2 repeated measures ANOVA was used to examine the effect of trial (valid vs. invalid), emotion (angry vs. neutral), and BI status (BI vs. BN). To test for group differences in the affective Posner task, an independent sample *t*-test was used to examine the effect of BI status on angry and neutral validity scores.

To test the relation between the two tasks, and for potential variation in this relation by BI status, we employed a hierarchical regression predicting AB in the dot-probe task using BI, AB in the affective Posner task (angry validity score), and their interaction (mean centered). To probe the interaction, we tested the correlation between tasks for each group (BI and BN) separately.

Next, we evaluated the association of AB pattern with anxiety, creating four groups based on median split (Median\textsubscript{dot-probe}=-0.37; Median\textsubscript{Posner}=5.00): a group with high bias scores in both tasks (N=25), a group with high bias scores in the dot-probe and low angry validity scores in the affective Posner (N=22), a group with low bias scores in the dot-probe and high validity scores in the Posner (N=21), and a group with low scores
in both tasks (N=25). To test the three hypotheses related to this aim, we employed a one-way ANOVA with polynomial contrasts to allow non-linear relations. Finally, to explore the association between BI and AB pattern across tasks, we tested the significance of the three-way interaction of BI status, dot-probe bias, and affective Posner bias in predicting anxiety via hierarchical regression.

**Results**

**BI, Anxiety, and AB towards Threat**

In the dot-probe task, there was no difference between BI and non-BI children in AB towards threat, $t(109)=0.59, p=.56, d=0.11$. Moreover, neither group displayed a significant bias, $t’s<0.58, p’s>.56, d’s<0.15$ (Figure 1 & Table 1).

For the affective Posner task, we noted a significant main effect for validity score, $F(1,107)=8.78, p=.004, \eta^2=.08$. Participants were slower to respond to incongruent trials ($M_{\text{Valid}}=446.23, SD=66.88; M_{\text{Invalid}}=454.20, SD=66.37$), $t(108)=-2.64, p=.01, d=-0.12$, regardless of emotion-cue and BI status. No other main effects or interactions were significant. Given the *a priori* hypotheses of differences in angry validity scores between BI and BN children (E. Fox et al., 2001), we performed independent sample $t$-tests (Figure 1 & Table 1). BI children had a significantly greater validity score for angry faces ($M=14.47, SD=33.24$) than BN children ($M=0.81, SD=37.42$), $t(107)=-1.98, p=.050, d=-0.39$. This effect was not significant when evaluating the neutral validity score ($p=.17$).
The only significant predictor of social anxiety was BI, \( r(112)=.52, p<.0001 \) (Table 1). There were no significant relations between anxiety, gender, and AB on either task.

Figure 2-1: Differences in AB towards threat in the dot-probe and affective Posner tasks between BI and BN children. Error bars represent standard error.
Table 2-1: Means and standard deviations of main variables by BI status.

<table>
<thead>
<tr>
<th>Variable</th>
<th>BI</th>
<th>Non-BI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>% Boys</td>
<td>48.0% (SD)</td>
<td>48.4% (SD)</td>
</tr>
<tr>
<td>IQ</td>
<td>108.74 (14.58)</td>
<td>111.13 (12.27)</td>
</tr>
<tr>
<td>Threat Bias (ms)</td>
<td>-0.51 (15.98)</td>
<td>1.20 (16.29)</td>
</tr>
<tr>
<td>Neutral Validity Effect (ms)</td>
<td>15.23 (43.45)</td>
<td>5.19 (31.57)</td>
</tr>
<tr>
<td>Angry Validity Effect (ms)</td>
<td>14.47 (33.24)</td>
<td>0.81 (37.42)</td>
</tr>
<tr>
<td>Social Phobia</td>
<td>4.17 (3.87)</td>
<td>0.61 (1.94)</td>
</tr>
</tbody>
</table>

Note: Bolded = p<.05.

**Relations between AB Tasks**

Across the entire sample, there were no significant relations between the threat bias score from the dot-probe task and angry or neutral validity scores from the affective Posner task, r’s<.20 and p’s>.06. However, in the hierarchical regression predicting dot-probe threat bias using BI and angry validity score as predictors, the relation between dot-probe threat bias and Posner angry validity score was dependent on BI status, β=0.52, p=.0002. Performance in the two tasks was positively associated in the BI group, r(37)=.56, p=.0002, but not in the BN group, r(52)=-.24, p=.08 (Figure 2). Moreover, the two relations were significantly different from each other, z=4.02, p=.0001. Neither the overall regression model nor the interaction was significant when evaluating the relation between threat bias and neutral validity score.
Patterns of AB, BI, and Anxiety

To evaluate the pattern of AB across tasks in relation to anxiety, we created four groups based on median split. BI status was not equally represented among the groups, $\chi^2(3, N=93)=11.75, p=.008$. Further probing the chi-square test revealed that there were significantly more BI children in the group with high bias scores in both tasks (Adjusted Standardized Residual=2.1) and significantly fewer BI children in the group with high dot-probe bias scores and low affective Posner bias scores (Adjusted Standardized Residual=-3.1) than expected by chance (Table 2 & Figure 3). This unequal group
distribution did not allow us to test the three-way interaction evaluating the association between BI and AB pattern across tasks in predicting level of anxiety.

Table 2-2: Means and standard deviations of main variables by attention bias group.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Low DPB Low POS</th>
<th>Low DPB High POS</th>
<th>High DPB Low POS</th>
<th>High DPB High POS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>N</td>
<td>25</td>
<td>21</td>
<td>22</td>
<td>25</td>
</tr>
<tr>
<td>% Boys</td>
<td>44.0%</td>
<td>52.4%</td>
<td>54.5%</td>
<td>48.0%</td>
</tr>
<tr>
<td>% BI</td>
<td>52.0%</td>
<td>38.1%</td>
<td>13.6%</td>
<td>60.0%</td>
</tr>
<tr>
<td>Threat Bias (ms)</td>
<td>-14.65</td>
<td>-10.85</td>
<td>12.63</td>
<td>13.53</td>
</tr>
<tr>
<td></td>
<td>(8.13)</td>
<td>(7.92)</td>
<td>(9.07)</td>
<td>(11.28)</td>
</tr>
<tr>
<td>Neutral Validity</td>
<td>-5.84</td>
<td>14.52</td>
<td>3.22</td>
<td>26.92</td>
</tr>
<tr>
<td>Effect (ms)</td>
<td>(29.65)</td>
<td>(30.77)</td>
<td>(32.65)</td>
<td>(38.59)</td>
</tr>
<tr>
<td>Angry Validity</td>
<td>-21.84</td>
<td>35.24</td>
<td>-21.82</td>
<td>32.88</td>
</tr>
<tr>
<td>Effect (ms)</td>
<td>(17.41)</td>
<td>(21.54)</td>
<td>(24.79)</td>
<td>(21.09)</td>
</tr>
<tr>
<td>Social Phobia</td>
<td>2.52</td>
<td>1.19</td>
<td>1.32</td>
<td>3.08</td>
</tr>
<tr>
<td></td>
<td>(3.91)</td>
<td>(2.66)</td>
<td>(2.84)</td>
<td>(3.45)</td>
</tr>
</tbody>
</table>

*Note: DPB=Dot-probe task; POS=Affective Posner task.*
Thus, we examined the interaction between tasks, independent of BI, using a one-way ANOVA with polynomial contrasts (Figure 4). The main effect of bias group on anxiety was not significant, $F(3,89)=1.83, p=.15, \eta^2=.06$. However, there was a significant quadratic effect, $F(1,89)=5.11, p=.026, 95\% \text{ CI}[0.19, 2.91]$, indicating that anxiety was higher in the two groups with consistent bias (high-high and low-low groups) versus the two groups with inconsistent bias scores (high-low and low-high groups).

Neither the ANOVA nor the quadratic contrast was significant, $F$’s<0.86, $p$’s>.36, when controlling for BI, signifying that this finding was dependent on BI status. If the bias groups are created with neutral validity scores rather than angry validity scores, there was no relation with anxiety or a distinct BI distribution across groups.

Figure 2-3: Proportion of BI and BN children by group of cross-task AB patterns. DPB=Dot-probe task; POS=Affective Posner task.
Discussion

The current study examined the relation between AB measured with the dot-probe and affective Posner tasks in children at risk for anxiety. We did not find AB differences between BI and BN children in the dot-probe task. However, BI children showed a larger AB to threat in the affective Posner task compared to BN children. The cross-task correlation of AB was associated with temperamental risk, such that AB was related across tasks only in BI children. Finally, children who were consistently biased across tasks (showing high or low scores in both tasks, rather than high in one but low in the
other) had elevated levels of anxiety.

As expected, BI children displayed a significantly larger validity score to angry faces than the BN children during the affective Posner task. Although we cannot presume a specific bias to angry faces (as the ANOVA comparing to neutral trials was not significant), this significant difference is in line with previous studies with adults, showing that anxious individuals display larger validity scores to threatening stimuli (E. Fox et al., 2001). The specific mechanisms underlying the validity effect remain unclear. The common interpretation is that anxious individuals are slower to disengage attention from threatening stimuli. However, this interpretation has been criticized because it assumes that the abrupt onset of a single stimulus draws attention (engagement) equally for anxious and non-anxious individuals, regardless of the emotional valance of the stimulus (Clarke, MacLeod, & Guastella, 2013). Moreover, there may be non-attentional processes that influence RTs, such as behavioral freezing in the presence of threat stimuli by anxious individuals (Mogg et al., 2008). Even though these issues complicate the interpretation of mechanisms underlying AB in the affective Posner task, our findings indicate differences in information processing between BI and BN that parallel the findings from the adult anxiety literature.

In contrast, there were no differences between BI and BN in the dot-probe task. Although the lack of association between performance on the dot-probe and BI or anxiety ran contrary to some previous studies (Pérez-Edgar et al., 2010), the current findings are not surprising given that other studies with BI children have not found this association (Pérez-Edgar et al., 2011; White et al., 2017). Indeed, the inconsistency of findings with the dot-probe task inspired the current study.
AB to threat is likely to have implications for real-world social behavior when it is “consistent”—that is, evident across contexts and attention processes. Previous studies examining convergence between AB measures have found no relation between the dot-probe and other tasks (Broeren et al., 2011; Brown et al., 2014; Dalgleish et al., 2003). This may have been due to the non-similarity between tasks (e.g., dot-probe vs. Emotional Stroop). These null findings likely also reflect the lack of, or failure to account for, a “primed” population of study. Indeed, the current study failed to find a relation between tasks for the whole sample. If threat bias convergence across tasks is itself an important indicator of an individual’s threat-related attention processing—the consistency of biases in their attention processing—then we would expect this relation to depend on other factors, such as temperamental risk for anxiety. We find that the relation among tasks was significantly stronger among BI children versus their non-BI peers.

BI children were underrepresented among individuals with inconsistent bias, so it was not possible to evaluate if displaying a bias in both tasks and being BI conferred an added risk for anxiety. Nevertheless, the pattern of AB across tasks was related to anxiety level for the sample as a whole. Specifically, children who displayed a consistent bias in both tasks, regardless of direction (bias towards or away from threat), had higher levels of anxiety. While the “high-high” group met our pre-study predictions, the “low-low” group was somewhat unexpected. It is possible that the lack of difficulty disengaging from threat in the Posner task taps an underlying skill that allows for the avoidance pattern evident in the Dot-Probe task. Within the AB literature, some studies find anxiety to be related to a bias towards threat (Bar-Haim et al., 2007; Pérez-Edgar et al., 2010), while others find a bias away from threat (Brown et al., 2013; Mansell et al., 1999; Morales et
Consistent biases toward or away from threat may have distinct implications for adaptive functioning, resulting in heightened or diminished exposure to threat when processing social information, respectively. Future studies should investigate if individuals with stable biases toward or away from threat represent subtypes of risk for anxiety; these opposite extremes of threat bias may differentiate between disorders related to distress (heightened threat bias) and fear (initial vigilance followed by threat avoidance; Salum et al., 2013; Waters et al., 2014).

Future research should also examine AB using eye-tracking measures. Eye-tracking provides more direct measures of attention without relying on RTs, which intermingle cognitive, affective, and motoric processes triggered prior to and after the presentation of the response cue. More nuanced measures of attention may help elucidate the attentional processes that underlie the observed differences in RT paradigms, allowing us to better understand AB towards and away from threat and their implications for socioemotional development.

**Conclusion**

To our knowledge, this is the first study to demonstrate convergence across AB measures in children. The two tasks only showed a relation in BI children. In turn, showing a consistent bias across the two tasks, regardless of bias direction (towards or away), was associated with elevated anxiety. These findings illustrate the importance of examining patterns of attention across tasks, while also considering individuals’
socioemotional predispositions. These findings have the potential to aid the early identification of children at risk for anxiety and help develop treatments (e.g., AB modification training) that target more specific and individualized attention processes to shift maladaptive developmental trajectories.
Chapter 3

Study 2: Maternal Anxiety Predicts Attentional Bias Towards Threat in Infancy

Authors: Santiago Morales, Kayla M. Brown, Bradley C. Taber-Thomas, Vanessa LoBue, Kristin A. Buss, and Koraly E. Pérez-Edgar


Abstract

Although cognitive theories of psychopathology suggest that attention bias towards threat plays a role in the etiology and maintenance of anxiety, there is relatively little evidence regarding individual differences in the earliest development of attention bias towards threat. The current study examines attention bias towards threat during its potential first emergence by evaluating the relations between attention bias and known risk factors of anxiety (i.e., temperamental negative affect and maternal anxiety). We measured attention bias to emotional faces in infants (N=98; 57 male) ages 4 to 24 months during an attention disengagement eye-tracking paradigm. We hypothesized that: 1) there would be an attentional bias towards threat in the full sample of infants, replicating previous studies, 2) attentional bias towards threat would be positively related to maternal anxiety, and 3) attention bias towards threat would be positively related to temperamental negative affect. Finally, 4) we explored the potential interaction between
temperament and maternal anxiety in predicting attention bias towards threat. We found that attention bias to the affective faces did not change with age, and that bias was not related to temperament. However, attention bias to threat, but not attention bias to happy faces, was positively related to maternal anxiety, such that higher maternal anxiety predicted a larger attention bias for all infants. These findings provide support for attention bias as a putative early mechanism by which early markers of risk are associated with socioemotional development.

**Introduction**

A wealth of research suggests that attentional bias towards threat—the propensity to selectively attend to threatening environmental cues—may play a role in the etiology and maintenance of anxiety (Bar-Haim et al., 2007). Anxiety most often first emerges by mid-adolescence (Beesdo et al., 2007), suggesting that causal mechanisms should also be evident in childhood. However, there is relatively little evidence regarding the early development of attentional bias (Field & Lester, 2010). The available data suggest that normative threat-related biases emerge during infancy. For instance, 7-month-old infants attend for longer periods of time towards threat-related stimuli compared to neutral stimuli while a distractor is present (Peltola et al., 2008). While factors that place children at risk for anxiety are likely in play early in development, few studies have examined the relation between attentional biases in infancy and individual risk factors for the development of anxiety. Based on the broader literature, infant temperament (Clauss & Blackford, 2012) and maternal anxiety (Merikangas, 2005) are both likely to impact early
anxiety processes. The present study examines: 1) the pattern of attentional bias towards threat in a cross-sectional sample of young (4 to 24 months) infants, 2) the relation between attention bias towards threat and the infant’s temperament, 3) the relation between attentional bias towards threat and maternal anxiety, and 4) the potential interaction between temperament and maternal anxiety in predicting attention bias towards threat.

A growing corpus of studies suggests that individuals with high trait or clinical anxiety show an attention bias to threat (Bar-Haim et al., 2007). This bias is pervasive across anxiety disorders: evident in children and adults, across type of anxiety diagnoses, and among individuals with clinical anxiety as well as high trait anxiety (Bar-Haim et al., 2007), making it an important marker for the disorder. A direct extension of these findings has been the creation of interventions designed to reduce anxiety by manipulating the level of bias (through Attention Bias Modification Training; ABMT). Initial investigations showed great promise, as modulating attention bias subsequently reduced levels of anxiety and sensitivity to stress (Bar-Haim, 2010; Hakamata et al., 2010; MacLeod & Clarke, 2015), providing mechanistic evidence that attention bias to threat may play a causal role in the emergence of anxiety (Van Bockstaele et al., 2014). This has led ABMT to be used as treatment for anxiety (e.g., Amir, Beard, Burns, & Bomyea, 2009) or as a complementary treatment together with cognitive behavioral therapy (e.g., Shechner et al., 2014). However, recent findings indicate that attention bias away from threat is also related to anxiety (Brown et al., 2013; Salum et al., 2013; Waters et al., 2014). Importantly, most of this work has been done in adults, even though vulnerability for anxiety has its roots early in development (Pine et al., 1998; Pine & Fox,
— a period that may present a critical target for intervention. Understanding the normative developmental patterns of attention bias is a crucial step in delineating how and why opposing patterns of attention may emerge later in life.

A bias, or systematic preference towards threat-related emotional facial expressions, seems to emerge around 7 months of age. For instance, 7-month-olds spontaneously look longer at fearful facial expressions than at happy expressions (C. A. Nelson & Dolgin, 1985). Similarly, 8- to 14-month-olds orient faster towards angry faces over happy faces when presented side-by-side (LoBue & DeLoache, 2010). Beyond measures of visual attention, a bias is also evident in attention-related electrophysiological measures. In particular, infants display heightened brain responses to fearful faces compared to happy and neutral facial expressions (Leppänen, Moulson, Vogel-Farley, & Nelson, 2007; C. A. Nelson & De Haan, 1996; Peltola, Leppänen, Maki, & Hietanen, 2009). Finally, attention bias towards threat-related stimuli is not specific to human faces. From infancy through childhood and into adulthood individuals display a bias towards non-social threat-related stimuli like snakes and spiders (LoBue, 2010; LoBue & DeLoache, 2008, 2010). For example, 8- to 14-month-old infants were quicker to orient towards snakes compared to frogs (LoBue & DeLoache, 2010). Finally, 4- to 24-month-olds are faster to orient to stimuli that appeared in the same spatial location of previously presented snakes compared to frogs, and angry faces versus happy faces (LoBue, Buss, Taber-Thomas, & Pérez-Edgar, 2016). Together these findings suggest the presence of an attention bias towards social and non-social threat cues during infancy.

Given that attention is not a unitary construct (Petersen & Posner, 2012) and attention bias may emerge at different stages of the attentional process (e.g., orienting vs.
disengagement; Cisler & Koster, 2010), recent research has examined attentional bias in the infant’s ability to disengage from emotionally salient stimuli. These studies often use an affective version (Peltola et al., 2008) of the overlap task (Aslin & Salapatek, 1975; Hood, Willen, & Driver, 1998). In the affective overlap task, infants are presented with a central affective stimulus (e.g., an emotional facial expression). After a short delay (e.g., 1000ms), a peripheral target appears (i.e., a distractor), while the central stimulus remains present for the rest of the trial (e.g., 3000ms).

Using this paradigm, studies have found that by 7 months infants are less likely to disengage from a fearful face than a happy or neutral facial expression when presented with a distractor (Leppänen et al., 2010; Peltola et al., 2008; Peltola, Leppänen, Vogel-Farley, Hietanen, & Nelson, 2009). Moreover, studies have found that difficulty disengaging from fearful faces is accompanied by cardiac deceleration, a psychophysiological marker of attention allocation (Leppänen et al., 2010; Peltola, Leppänen, & Hietanen, 2011). Emerging evidence suggests that biased disengagement patterns have implications in later socioemotional development, as heightened attention bias to fearful faces at 7 months predicts attachment security at 14 months, with a smaller bias associated with insecure attachment (Peltola, Forssman, Puura, van IJzendoorn, & Leppänen, 2015). Overall, these studies suggest a normative pattern of information processing that is biased towards threatening stimuli from infancy.

Side-by-side, the adult and the infant literature may seem inconsistent. On the one hand, the developmental literature suggests that attention bias to threat is normative and predictive of a secure attachment. In contrast, the clinical literature considers attention bias to threat to be a mechanism for anxiety. This seeming inconsistency may arise from
the fact that we know little regarding individual differences in these early biases and their potential role in the development of anxiety. It is likely that individual vulnerabilities to anxiety emerge from underlying, normative patterns of attention to threat (Field & Lester, 2010a; Morales, Fu, & Pérez-Edgar, 2016). In addition, much of the clinical and developmental literature with older children has used angry faces to represent threat (Roy et al., 2015). The normative infant literature, in contrast, has used fearful faces to represent threat (Peltola, Hietanen, Forssman, & Leppänen, 2013; Peltola et al., 2008; Peltola, Leppänen, Maki, et al., 2009). Although both angry and fearful faces are threat-related stimuli, angry facial expressions are believed to signal a threat from the individual making the expression to the receiver. In contrast, fearful facial expressions are believed to indicate to the receiver that the expresser perceives an external threat in the environment (Adams and Kleck, 2003). Since our core interest is in linking variations in early attention bias to the larger anxiety-risk literature, we use angry faces in the current study. Thus the present study evaluates the relation between early attention biases and known risk factors for the development of anxiety, specifically children’s temperament and maternal anxiety.

Fearful temperament is one of the best early predictors of anxiety (Degnan & Fox, 2007; Pérez-Edgar & Fox, 2005b). Within the literature, fearful temperament is often approached as an overarching construct encompassing specific conceptualizations such as behavioral inhibition (Kagan & Fox, 2006), negative affectivity (Rothbart & Bates, 2006), shyness (Rapee & Coplan, 2010), dysregulated fear (Buss, 2011), and neuroticism (Eysenck, 1967), to name a few. These varying characterizations of fearful temperament share several key components (e.g., high withdrawal, inhibition to novelty, sensitivity to
negative stimuli, and limbic/amygdala over activity; Nigg, 2006). Children who display these patterns of behaviors or responses are likely to be characterized as having a fearful temperament, and are at a four- to seven-fold increased risk for anxiety disorders, particularly social anxiety disorder (Buss et al., 2013; Chronis-Tuscano et al., 2009; Clauss & Blackford, 2012).

In infancy, many of the hallmark measures of fearful temperament (e.g., withdrawal, avoidance) are not developmentally appropriate. However, previous studies have noted that children characterized as temperamentally fearful also display high levels of negative affect and increased physiological reactivity in novel situations (N. A. Fox et al., 2005). Negative affect in infancy is associated with later fearful temperament (N. A. Fox, Henderson, Rubin, Calkins, & Schmidt, 2001). Given the age range of the current sample (4 to 24 months), we use a well-validated measure of negative affect as our developmentally sensitive marker of fearful temperament. Thus, our current data will speak to the impact of negative affect.

Pérez-Edgar and colleagues (2010) found that children characterized as temperamentally fearful as toddlers displayed a bias towards threat as adolescents. Moreover, several studies have found that early fearful temperament when coupled with attention bias towards threat predicts later social withdrawal and anxiety (Cole, Zapp, Fettig, & Pérez-Edgar, 2016; Morales et al., 2015; Pérez-Edgar et al., 2010, 2011; White et al., 2017). However, few studies have evaluated the relation between attention bias and temperament during the developmental period when these constructs first emerge. One exception is a recent study in which at 12 months of age, infants higher in negative affect displayed greater attention bias to threat—as measured by difficulty disengaging from
fearful faces (Nakagawa & Sukigara, 2012). These data suggest that attention bias to threat may be associated with fearful temperament from early infancy.

Another strong predictor of the emergence of anxiety in children is maternal anxiety. Familial aggregation studies find that there is a three- to five-fold increased risk of anxiety disorders among children of anxious mothers (Merikangas, 2005). For example, children of mothers with an anxiety disorder had an heightened risk (hazard ratio=1.3) of developing any anxiety disorder, relative to children of mothers without an anxiety disorder before adulthood (Schreier, Wittchen, Höfler, & Lieb, 2008). Moreover, children of anxious mothers display an attention bias towards threatening stimuli, compared to children of non-anxious mothers—although this effect may be specific to daughters (Mogg, Wilson, Hayward, Cunning, & Bradley, 2012; Montagner et al., 2015). In the only study examining the impact of maternal characteristics on attention bias during infancy, infants whose mothers reported high levels of stress and depression displayed a heightened attention bias towards fearful faces (Forssman et al., 2014).

Although temperament and maternal anxiety are established as independent risk factors of anxiety, it is likely they are in fact interrelated. For instance, children are more likely to be characterized as temperamentally fearful when their parents have an anxiety disorder (Rosenbaum et al., 2000; Shamir-Essakow, Ungerer, & Rapee, 2005). In addition, highly fearful children may be especially sensitive to anxiety-related behaviors of anxious mothers (e.g., mothers’ expressed anxiety; Aktar, Majdandžić, de Vente, & Bögels, 2013), consistent with variations in differential susceptibility to the environment (Belsky & Pluess, 2009). This implies that there are shared underlying psychosocial (e.g., parenting; Whaley, Pinto, & Sigman, 1999) and biological (e.g., genetics; Robinson,
Kagan, Reznick, & Corley, 1992) mechanisms. It is possible that both factors not only contribute to the development of attention bias towards threat, but also interact to predict attention bias.

The present study evaluates the relation between infant attention bias towards threat and known risk factors for the development of anxiety. Particularly, we examine infants’ attention bias to threat and its relation to negative affect (as marker of fearful temperament) and maternal anxiety. Based on the reviewed literature we hypothesize that: 1) there will be an attentional bias towards threat across the sample in infancy, replicating previous studies (e.g., Peltola et al., 2008), 2) the magnitude of attention bias towards threat will be positively related to negative affect and 3) attentional bias towards threat will be positively related to maternal anxiety. Finally, 4) we explore if temperament and maternal anxiety interact to predict attention bias towards threat. We hypothesize that infants high in temperamental negative affect who also have mothers high in anxiety would display the highest levels of attention bias to threat.

**Methods**

**Participants**

Participants in the current study (N=98; 57 male; Mean \( \text{age} \)=13.30 months; \( \text{SD}_{\text{age}}=5.64; \text{Range}_{\text{age}}=4-24 \) months) were part of a larger multi-task study examining the relation between attention and temperament. Participants were identified either through a university sponsored database or recruited through community advertisement.
The initial sample of participants (N=238) was predominantly Caucasian (87.8%), which reflects the surrounding rural community. The remaining 11.3% of families self-identified as Asian-American, African-American, Native-American or Hispanic. Infants were born within three weeks of their due date, experienced no major complications, and had adequate birth weight (Mean_weight = 7.67 lbs, SD_weight = 1.18). Infants met developmental milestones (rolling over, crawling, walking) within normal time windows. None of the study variables (other than age) were associated with the timing and attainment of motor milestones (p’s > .10).

Of the initial 238 kids, 145 attempted the current task. We did not attempt the task if the infant was distressed or fussy. If the infant was unable to calibrate at the start of the task or stopped attending during the task, he/she was designated as not having completed the task (N=24). We then assessed the quality of the collected data after the visit. We first examined calibration data using the X-Y coordinates of the infant’s eye gaze relative to the location of the 5 calibration points. If the deviation of the coordinates was greater than four degrees from the calibration points, the child was excluded from further processing (N=13). This is in line with reviews suggesting that initial calibration is crucial to providing robust and reliable data (e.g., Morgante, Zolfaghari, & Johnson, 2012). Infants were also excluded from the analysis if mothers did not provide data regarding their anxiety (N=10). As such, eye tracking and questionnaire data were available from 98 infants. The only significant difference between infants who provided usable data and those who did not was age, in that older babies provided more usable data, t(125) = -2.08, p=0.04, d=0.37.

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

Measures

**Infant temperament.** Due to the wide age range in the current study, we captured temperamental negative affect using one of two developmentally-appropriate questionnaires.

*Infant Behavior Questionnaire Revised (IBQ-R).* Mothers of 4- to 12-month-old infants \((N=43, 27 \text{ males, } \text{Mean}_\text{age}=8.39 \text{ months, } \text{SD}_\text{age}=2.79)\) rated their infants’ temperament on the IBQ-R Short form (Putnam, Helbig, Gartstein, Rothbart, & Leerkes, 2014). The IBQ-R Short form is a 91-item scale, in which parents rate the frequency of specific infant behaviors as they occurred in the previous week using a seven-point scale with an eighth option for ‘Does not apply’. For this study, we used the Negative Affect factor, composed of the sadness, distress to limitations, fear, and reactivity/recovery subscales \((\text{Mean}=3.62, \text{SD}=0.47, \text{Cronbach’s } \alpha=.795)\).

*Toddler Behavior Assessment Questionnaire (TBAQ).* For infants between 12 and 24 months \((N=55, 30 \text{ males, } \text{Mean}_\text{age}=17.21 \text{ months, } \text{SD}_\text{age}=4.06)\), mothers completed the TBAQ (Goldsmith, 1996). The TBAQ is a 120-item questionnaire, in which parents rate the frequency of specific toddler behaviors as they occurred in the past month using a seven-point Likert scale with an eighth option for ‘Does not apply’. The present study uses the ‘Negative Affect’ factor, which is composed of the sadness, anger, social fear, and object fear subscales \((\text{Mean}=3.21, \text{SD}=0.57, \text{Cronbach’s } \alpha=.813)\).
**Questionnaire Composite of Temperament.** There were no differences in sex, birth-weight, or other demographics (p’s>0.34) between the young infants characterized by the IBQ and the older infants characterized by the TBAQ. We standardized negative affect scores within each group of infants characterized by either the IBQ or the TBAQ. We then merged each infant’s score into a single negative affect variable used to capture variation in negative affect (Mean=−0.03, SD=1.05 for overall sample).

**Maternal anxiety.** Mothers completed the Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1988), a 21-item self-report scale that measures anxiety symptoms during the past month. Each item is rated on a 4-point scale from 0 (“Not at all”) to 3 (“Severely”). In the current sample, this measure had adequate reliability (Cronbach’s α = .879). Given the skewness and kurtosis of our data (Mean=4.46, SD=5.62, Median=3.00, Skew=2.17, Kurtosis=5.94), we transformed BAI scores by taking the log plus one, log(x + 1). The transformed variable had a more adequate distribution (Mean=1.26, SD=0.95, Median=1.39, Skew=0.15, Kurtosis=−0.98) and was used for the analyses, tables, and figures.

**Attention bias.** The overlap task consisted of 12 experimental trials. Trials were triggered by infant fixation rather than pre-determined presentation timing (Oakes, 2012). 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. The fixation stimulus was then followed by one of three types of faces taken from the NimStim face stimulus set (Tottenham et al., 2009): Angry, Happy, or Neutral. As in Peltola et al. (2015), faces appeared on the screen for 1000ms followed by the distractor, which appeared together with the face for 3000ms. The distractor consisted of a static black-and-white
checkerboard patterned rectangle that appeared vertically oriented on the edge of either the left or right side of the screen (counterbalanced). Twelve faces were used (half male). The face pictures were each 11.8cm X 8.5cm, the distractor was 12.0cm X 2.0cm with a distance of 22.5 cm between their centers. Task presentation was controlled by Experiment Center (SensoMotoric Instruments, Teltow, Germany).

**Eye-Tracking.** The eye-tracking data were obtained using a RED-m Eye Tracking System (SensoMotoric Instruments, Teltow, Germany) and an integrated 22-inch presentation monitor. Infants were seated approximately 60 cm from the monitor on either an adjustable highchair, or their mother’s lap, such that their eye gaze was centered on the screen. Infants’ eye gaze was calibrated using a 5-point calibration procedure using an animated multicolored circle. Gaze information was sampled at 60 Hz and collected by Experiment Center.

Areas of interest (AOI) that delineated the top, bottom, and contour of the face and probe locations were created using BeGaze (SensoMotoric Instruments). Subsequent analyses were based on gaze data within the specified AOIs. Fixations, defined as gaze maintained for at least 80 milliseconds within a 100 pixel maximum dispersion, were extracted with BeGaze. Dwell times within the face AOIs were extracted with BeGaze, supplemented with custom-made Python (Python Software Foundation, [http://www.python.org/](http://www.python.org/)) and MATLAB (The MathWorks, Inc., Natick, Massachusetts, USA) scripts. Dwell times were calculated as the total amount of time fixated on a face while the distractor was present for each trial. Although this measure is different than in previous studies using this task (e.g., Peltola et al., 2015), we believe this measure captures attention bias with our version of the task. As a continuous measure, dwell time
allows us to create attention bias scores akin to the ones used in the broader attention bias literature (i.e., difference score). Moreover, previous studies utilizing the affective overlap task have used dwell time as their measure of attention (Heck, Hock, White, Jubran, & Bhatt, 2016). Data were subsequently analyzed using R (R Development Core Team, 2008).

**Statistical Analyses**

A repeated measures ANOVA under a mixed effects modeling framework was used to evaluate the presence of an overlap effect by testing for differences in infants’ average dwell time to each emotion face (angry, happy, and neutral) while the distractor was present. In order to evaluate the effects of age, maternal anxiety, and fearful temperament on the attention bias scores towards happy and angry faces, a mixed effects model equivalent to a repeated measures ANCOVA was run for each predictor. We used mixed effects models as they allow us to examine the effects of the predictors as continuous variables and use all available data (as opposed to GLM which uses listwise deletion). Given that mixed effects models do not produce standard effect sizes as variance parameters are estimated directly using maximum likelihood, we provided estimated effect sizes based on GLM.

Given that our hypotheses are specific to attention bias towards threat, the effects of interest were the two-way interactions between the emotion of the attention bias scores (angry or happy) and each of the continuous predictor variables of interests (i.e., age, maternal anxiety, and negative affect). These interactions evaluated if the relation
between attention bias scores and the continuous predictor variables differed across affect
condition (angry or happy faces). Finally, to explore if negative affect and maternal
anxiety interacted to predict attention bias towards threat, we evaluated one model with
both temperament and maternal anxiety as continuous predictor variables. In this model,
the effect of interest was the three-way interaction: emotion condition by negative affect
by maternal anxiety.

In completing our analyses, we also assessed the quality of the infant data. For
dwell time we noted that the data were normally distributed (Skew < |1|, Kurtosis < |1|)
and inspected for outliers. For the analyses presented below, almost half of the infants
provided good data (i.e., at least one 80-ms fixation) for all 12 trials (43.88%) and most
infants (77.55%) provided good data on at least 10 trials. In order to verify that the
findings were not driven by the number of trials, we reran all analyses while controlling
for number of trials. The results did not change. Moreover, we again reran all analyses
removing participants with trials under 1.5 SDs (328.12 ms) in average dwell times and
found the same results. Finally, in a more conservative analysis, we only analyzed the
data for participants who had at least three valid trials per condition and again the pattern
of results remained the same.

Results

Although 98 infants provided data for the analyses, not all infants provided data in
every condition. On average, infants provided data on approximately 3.5 trials per
condition ($M_{\text{neutral}} = 3.45$, $SD = 0.86$, Median = 4 trials; $M_{\text{happy}} = 3.51$, $SD = 0.86$, Median
= 4 trials; $M_{\text{angry}} = 3.41$, $SD = 0.96$, Median = 4 trials). One child did not provide any valid fixations towards angry and happy faces and another child did not provide any valid fixations to happy faces. As illustrated in Figure 1, infant’s dwell time to the central face after distractor presentation differed according to face emotion, $F(2,191)=3.21$, $p=.04$, $\eta^2_p=.030$, suggesting a general effect of increased attention to emotion regardless of age ($M_{\text{neutral}} = 1255.58$, $SD = 646.90$; $M_{\text{happy}} = 1365.84$, $SD = 687.09$; $M_{\text{angry}} = 1394.06$, $SD = 673.27$). As predicted, infants dwelled more to the angry face compared to the neutral face, $t(96)=-2.28$, $p=.03$, $d=-0.23$. Importantly, there was no main effect or interaction with sex ($p$’s > .36). As such, sex was not analyzed further for parsimony.

Figure 3-1: Dwell time to the face while the distractor was present for each emotion. Error bars indicate within-subject 95% confidence intervals (Loftus & Masson, 1994).
Next, we created bias scores by separately calculating the difference of dwell time to each of the emotion faces (angry and happy) vs. neutral faces, yielding two bias scores (angry bias and happy bias); higher scores indicate increased bias to the emotion face. Four children were removed as outliers (>2.5 SD), one for bias to happy, one for bias to angry, and two for both. We then evaluated if these attention bias scores varied with age, negative affect, or maternal anxiety. The model evaluating the effects of age revealed no significant main effect, $F(1, 92) < 0.01, p = .99, \eta_p^2 = .000$, or interaction, $F(1, 89) = 0.11, p = .74, \eta_p^2 = .003$. Similarly, the main effect of, and interaction with, negative affect were not significant, $F(1, 93) = 0.04, p = .84, \eta_p^2 = .002$, and $F(1, 90) < 0.01, p = .96, \eta_p^2 = .000$, respectively.
However, the model with maternal anxiety showed a significant interaction, $F(1, 90) = 4.56, p = .04, \eta^2_p = .042$, indicating that the effect of maternal anxiety significantly differed for happy and angry attention bias scores. Specifically, as illustrated in Figure 2 and Table 1, maternal anxiety positively correlated with attention bias towards angry faces, $r(92)=.22, p=.03$, but not with attention bias towards happy faces, $r(91)=-.02, p=.88$. The two correlations significantly differed from each other, $Z=2.26, p=0.02$.

Table 3-1: Means, standard deviations, and correlations with confidence intervals.

<table>
<thead>
<tr>
<th>Variable</th>
<th>$M$</th>
<th>$SD$</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sex</td>
<td>-----</td>
<td>-----</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Angry Attention Bias</td>
<td>155.23</td>
<td>523.18</td>
<td>.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[-.01, .38]</td>
</tr>
<tr>
<td>3. Happy Attention Bias</td>
<td>148.78</td>
<td>522.48</td>
<td>.08</td>
<td>.49**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[-.13, .28]</td>
<td>[.32, .63]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Maternal Anxiety$^+$</td>
<td>1.26</td>
<td>0.95</td>
<td>.00</td>
<td>.22*</td>
<td>-.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[-.20, .20]</td>
<td>[.02, .40]</td>
<td>[-.22, .19]</td>
<td></td>
</tr>
<tr>
<td>5. Age</td>
<td>13.30</td>
<td>5.64</td>
<td>-.05</td>
<td>.00</td>
<td>-.01</td>
<td>-.04</td>
<td></td>
</tr>
<tr>
<td>6. Negative Affect</td>
<td>-0.05</td>
<td>1.06</td>
<td>.12</td>
<td>.04</td>
<td>.01</td>
<td>.33**</td>
<td>.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[-.08, .31]</td>
<td>[-.17, .24]</td>
<td>[-.19, .21]</td>
<td>[.14, .49]</td>
</tr>
</tbody>
</table>

Note. * indicates $p < .05$; ** indicates $p < .01$; $^+$Transformed maternal anxiety. $M$ and $SD$ are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). Boys were coded as 0 and girls as 1.
Finally, we examined whether negative affect and maternal anxiety interacted to predict attention bias. This final model revealed no interaction, $F(1, 88) = 1.47$, $p = .23$, $\eta_p^2 = .013$. However, the interaction of maternal anxiety with emotion remained significant, $F(1, 88) = 4.94$, $p = .03$, $\eta_p^2 = .051$, while controlling for the effects of temperament.

**Discussion**

The present study aimed to expand our knowledge of the development of attention biases by examining if: 1) a sample of young (4 to 24 months) infants displayed a bias towards threat; 2) attention bias towards threat was related to the child’s temperament; 3)
attentional bias towards threat was related to maternal anxiety; and 4) the interaction between temperament and maternal anxiety predicted attention bias towards threat.

Results suggest that the presence of an attention bias towards threat did not depend on the child’s age, gender, or negative affect. However, attention bias towards threat was positively related to maternal anxiety.

We found evidence for an attention bias towards threat during infancy, as indexed by increased attention to the threat-related stimuli compared to neutral stimuli. This is in line with previous research demonstrating that infants display an attention bias towards threat-related stimuli using behavioral (LoBue & DeLoache, 2010; C. A. Nelson & Dolgin, 1985; Peltola et al., 2008) and psychophysiological (Leppänen et al., 2010, 2007; C. A. Nelson & De Haan, 1996; Peltola et al., 2011; Peltola, Leppänen, Maki, et al., 2009) measures. Previous studies examining the development of this bias have found that it emerges between 5 and 7 months (Peltola et al., 2015, 2008; Peltola, Leppänen, Maki, et al., 2009). However, we did not find age-related changes, probably due to the wider age range (4-24 months) than previous studies and our use of age as a continuous measure rather than a categorical comparison factor. The current study is best suited to find a significant effect of age that takes the form of attention bias increasing (or decreasing) linearly with age. This pattern is different than previous studies that show age differences, in which age-related changes are evaluated by using two groups (e.g., 5-month olds vs. 7-month olds; Peltola, Hietanen, Forssman, & Leppänen, 2013; Peltola, Leppänen, Maki, et al., 2009). The current study is not able do a comparable analysis since it focused on recruiting a range of ages (e.g., there are only 6 children aged 5 months or younger). Future studies with a larger sample size should help disentangle the
differential findings. It may be that attention bias emerges around 7 months in this disengagement task, but once present this attention bias remains relatively stable and does not continue to increase with age.

The present study extended the current literature by examining the relation between attention bias and known risk factors of anxiety, namely fearful temperament and maternal anxiety. Due to the sample age, we employed negative affect as our marker of fearful temperament. Our data did not show a relation between attention bias and negative affect. This is in line with previous studies that fail to find a direct zero-order relation between fearful temperament and attention bias in infants (Forssman et al., 2014) as well as in older children (Cole et al., 2016; Pérez-Edgar et al., 2011; White et al., 2017). However, most of these studies find that attention bias to threat moderates the relation between fearful temperament and anxiety, such that only fearful children with an attention bias towards threat display high levels of social withdrawal and anxiety (Cole et al., 2016; Pérez-Edgar et al., 2010, 2011; White et al., 2017). The current study does not examine this interaction, as it would be developmentally inappropriate to evaluate anxiety in infants. Future longitudinal studies should evaluate this relation.

However, we did find that maternal anxiety was positively related to attention bias towards threat. Importantly, this relation was specific to attention bias towards threat and absent for attention bias towards reward (i.e., happy faces), even though the two bias scores were positively correlated ($r = .49$). This specificity is in agreement with previous studies that find a relation between maternal anxiety and attention bias towards threat in older children (Mogg et al., 2012; Montagner et al., 2015). Similarly, infants of mothers
who reported high levels of stress and depression display an attention bias to threat (Forssman et al., 2014).

The cause of the link between attention bias and maternal anxiety should be examined in future studies. It is possible that both genetic and environmental factors, as well as their interplay, create the relation between attention bias and maternal anxiety. For example, genetic factors, such as variations in the 5-HTTLPR allele, are related to anxiety and attention bias (Pergamin-Hight, Bakermans-Kranenburg, van IJzendoorn, & Bar-Haim, 2012). Similarly, genetically informed studies (e.g., twin studies) find that attention bias towards physical and emotional symptoms of anxiety (e.g., a “racing-heart”) have important genetic contributions (30-40% heritability; Eley & Zavos, 2010; but see Brown et al., 2013). This leaves environmental factors to explain a significant proportion of the variance.

There is evidence that learning through environmental transmission can lead to the development of anxiety and attention bias (Field & Lester, 2010b). For example, in the face of novel stimuli, parents provide cues and feedback that teach infants how to respond emotionally and behaviorally towards these stimuli. If parents provide fear-related information to older children (e.g., talking about or implying something is dangerous), it may lead to increased anxiety and attention bias (Field, 2006a, 2006b; Field & Lawson, 2003).

Finally, genetic and environmental factors do not operate independently. It is also possible that there are innate characteristics that predispose children to evoke specific environmental responses that in turn generate fear and anxiety. This may be at play here given the young age of our current sample. For instance, Brooker et al. (2015) found that
infant’s negative affect at 9 months predicted more anxiety symptoms in adoptive parents (mothers and fathers) 18 months later. This finding suggests that infants’ constitutional characteristics contribute to the development of parents’ characteristics that are believed to then impact children’s socioemotional development (Brooker et al., 2015). Moreover, inborn characteristics may also make children more sensitive to fear information (Aktar et al., 2013). Future research should examine mother-child interactions during the first months of life within a genetically informed design in order to unveil the developmental process that leads to heightened bias towards threat.

In the current study, we examined if children high in negative affect are more susceptible to anxiety levels in their mothers (e.g., Aktar et al., 2013). However, the data did not support this proposition as the interaction between maternal anxiety and negative affect was not significant. The null finding should be interpreted with caution, as this was an exploratory analysis with a relatively small sample size. It is important to note that although maternal anxiety and negative affect were related ($r = .33$), the effect of maternal anxiety and attention bias towards threat remained significant even while controlling for negative affect. This suggests that maternal anxiety may impact children’s processing of threat-related information from very early in development over and above any effects of temperament.

Interestingly, previous studies using the affective overlap task have found increased difficulty disengaging from fearful faces, compared to neutral and happy faces (e.g., Peltola et al., 2015, 2008). In the present study, we use angry faces as the threat-related stimulus, and find increased attention to the threat faces compared to neutral faces. However, we find no difference in attention bias between angry and happy faces.
Few studies have examined attention bias towards angry faces, and to our knowledge, no study has examined angry and fearful faces in the same study. Thus, it is unknown if different threat-related emotional biases develop in a similar manner and/or play distinct roles in the development of children. For example, Peltola and colleagues (2015) found that attention bias towards fearful faces predicted a secure attachment relationship while the present study finds that attention bias towards angry faces is related to maternal anxiety.

As a cross-sectional study, the current study is not able to examine the developmental significance of risk factors for anxiety and attention bias towards threat across time. Prospective longitudinal studies should examine the developmental relations between risk factors for anxiety and attention bias towards threat, as well as the long-term implications of this early attention bias in the emergence of anxiety. Finally, the effect sizes of the current findings are modest, suggesting that larger samples will be needed to capture the multiple mechanisms that contribute to socioemotional profiles.

Conclusion

The present study aimed to inform our understanding of the development of attention bias towards threat. Results support a growing literature suggesting that attention bias towards threat is present in early development. Even though attention bias towards threat did not change with age, it was positively related to maternal anxiety, a known risk factor for the development of anxiety. Together, the current findings imply
that attention bias towards threat during infancy, when combined with a focus on individual differences, shows promise as an early marker of socioemotional development.
Chapter 4

Study 3: The Role of Effortful Control in the Relation between Fearful Temperament and Attention Bias to Threat: a Multi-Method Exploration

Authors: Santiago Morales, Kristin A. Buss, and Koraly E. Pérez-Edgar

Status: In Prep

Abstract

Despite the importance of attention bias towards threat as a potential marker and intervention for anxiety, there are considerable inconsistencies in the literature. It is possible that these inconsistencies are due to individual differences in effortful control that interact with attention bias, functioning as either risk or protective factors for the link between attention bias and anxiety. However, the data regarding relations between attention bias, effortful control, and fearful temperament are inconclusive. Some theoretical models and empirical findings suggest that high levels of effortful control act as a protective factor, while others suggest it serves as a risk factor. In an attempt to clarify the role of effortful control, the present study employed several measures of effortful control (parent reports, behavioral, and neural markers) and examined its relation to attention bias, fearful temperament, and anxiety. Results mostly supported the model in which effortful control serves as a protective factor rather than a risk factor. Nevertheless, not all findings were in line with our hypotheses. The implications of these results are discussed in light of their limitations.
Introduction

Attention bias towards threat, the tendency to systematically attend to threatening environmental cues, has received considerable attention for its putative role in the acquisition and maintenance of anxiety. A wealth of research suggests that individuals with high trait or clinical anxiety show an attention bias (AB) to threat (Bar-Haim et al., 2007; Van Bockstaele et al., 2014). This bias is pervasive across anxiety disorders: evident in children and adults, across anxiety diagnoses, and among individuals with clinical anxiety as well as high trait anxiety (Bar-Haim et al., 2007), making it an important marker of anxiety. A direct extension of these findings has been the development of interventions aimed to reduce anxiety by manipulating the level of bias (through Attention Bias Modification Training; ABMT). Initial investigations showed great promise, as modulating AB subsequently reduced levels of anxiety and sensitivity to stress (Hakamata et al., 2010; MacLeod & Clarke, 2015), suggesting that AB to threat may play a causal role in the emergence of anxiety (Van Bockstaele et al., 2014). Although attention bias towards threat holds great promise as a marker for anxiety and its extension, ABMT, as a potential treatment for anxiety, the mechanisms through which AB operates are relatively unknown.

In addition, despite promising data in support for ABMT, other studies do not find a significant change in bias or a reduction in anxiety symptoms (Heeren et al., 2015). Similarly, recent studies have reported mixed findings regarding the relation between AB and anxiety – with studies failing to find the expected positive relation between AB and anxiety (Britton et al., 2012, 2013; Gotlib et al., 2004; Pineles & Mineka, 2005; Pishyar
et al., 2004; Waters et al., 2004) and other studies finding anxiety-linked attentional avoidance or bias away from threat (Brown et al., 2013; Mansell et al., 1999; Monk et al., 2006; Morales et al., 2015; Salum et al., 2013; Stirling et al., 2006; Waters et al., 2014). This inconsistency complicates the interpretation of AB to threat as a marker of anxiety, as well as its potential use as a therapeutic intervention.

It is possible that the inconsistency in findings reflects meaningful patterns of variability (Roy et al., 2015) although we lack the theoretical and methodological framework to interpret these patterns. For instance, there may be individual differences that interact with AB and serve as either risk or protective factors for the link between anxiety and AB, creating variability that cannot be explained until the role of such individual-level factors is explicitly considered. For instance, it has been proposed that self-regulatory factors, such as effortful control, may interact with anxiety-related AB to threat to predict anxiety (Lonigan et al., 2004).

Effortful control is commonly defined as “the efficiency of executive attention – including the ability to inhibit a dominant response and/or activate a subdominant response, to plan, and detect errors” (Rothbart & Bates, 2006, p. 129). Effortful control is believed to guide goal-directed behavior by monitoring performance and resolving conflict. Effortful control has been proposed to moderate the relation between anxiety and AB (Lonigan et al., 2004), such that the relation between anxiety and AB is only evident for individuals with low effortful control. In contrast, individuals high in effortful control are able to override their initial AB. For instance, Susa et al. (2012) found that only children (9-14 years) with an AB and low attentional control displayed high levels
of anxiety. High levels of attentional control seemed to erase the AB-anxiety link (Susa et al., 2012).

However, the role of effortful control in the relation between AB and anxiety is less clear in studies that consider other individual difference factors such as fearful temperament. Fearful temperament, most commonly studied as behavioral inhibition (BI), is characterized by increased sensitivity towards novelty, low approach tendencies, social withdrawal and reticence in childhood (Kagan, Reznick, Clarke, Snidman, & Garcia-Coll, 1984) and is predictive of a four- to seven-fold increased risk for anxiety (Buss et al., 2013; Clauss & Blackford, 2012; McDermott et al., 2009; Pérez-Edgar & Fox, 2005b). Paradoxically, different theoretical models have suggested that for fearful children, effortful control may act as either a protective factor (Henderson, Pine, & Fox, 2015; Lonigan & Phillips, 2001) or as a risk factor (Derryberry & Rothbart, 1997; Eisenberg & Fabes, 1992; Henderson et al., 2015; Pérez-Edgar, 2015) for the later emergence of anxiety.

In the first model, effortful control acts as a protective factor by regulating anxiety markers (e.g., fearful temperament and AB) in a top-down fashion. This model is in line with studies that demonstrate the positive impact of self-regulation capacities across the lifespan (e.g., Mischel, Shoda, & Rodriguez, 1989; Moffitt et al., 2011; Ursache, Blair, & Raver, 2012). Similarly, it is in line with theory and data suggesting that effortful control moderates the relation between anxiety or temperamental risk for anxiety and AB (Lonigan et al., 2004). For instance, studies find that only temperamentally fearful youth (9-18 years) who are also low in self-reported effortful control displayed a bias towards threat – fearful children who are high in effortful control do not display a bias (Lonigan
& Vasey, 2009; Susa, Benga, Pitica, & Miclea, 2014). However, a recent study (Cole et al., 2016) did not replicate this moderation using parent-report of effortful control in young children (age 5 years). The authors suggest that this may be because the children’s effortful control capacities were limited or immature. Another possibility is that parent report of children’s effortful control at this age may not be the best measure to capture the impact of effortful control on the AB-anxiety relation. Parent reports capture the parents’ conceptions of their child’s behavior rather than accurately measuring how the child behaves or the child’s self-regulatory abilities (Kagan & Fox, 2006). Thus, parent-report tends to best capture more apparent and observable behaviors such as externalizing behaviors (e.g., fighting or shouting; Kolko & Kazdin, 1993). Since children at this young age are not reliable reporters of their effortful control skills relative to older children, batteries of behavioral measures capturing effortful control have been developed for this age and even younger ages (e.g., Kochanska, Coy, & Murray, 2001; Rueda et al., 2004). It may be that behavioral measures of effortful control may be more sensitive in early childhood, which may better capture the role of effortful control in the AB-anxiety link.

Interestingly, a second set of studies using behavioral measures of effortful control find that increased effortful control relates to both increased anxiety (Price & Mohlman, 2007) and temperamental risk for anxiety (Lamm et al., 2014). Indeed, the combination of fearful temperament and high effortful control has been related to increased anxiety (Thorell, Bohlin, & Rydell, 2004; White, McDermott, Degnan, Henderson, & Fox, 2011). This is in line with the second model, which suggests that effortful control potentiates the child’s fear and wariness, rather than regulates them,
creating a positive feedback loop (Derryberry & Rothbart, 1997; Henderson et al., 2015). This is because effortful control may allow anxious and temperamentally fearful individuals to focus on anxiety-provoking thoughts (Price & Mohlman, 2007; White et al., 2011). In addition, temperamentally fearful children may be more cautious and monitor their performance more closely, which is reflected in increased effortful control (Henderson, 2010; White et al., 2011). If this increased effortful control capacity is not used flexibly, or used out of context (Henderson et al., 2015), it may result in rigid and overcontrolled behaviors, leading to withdrawal and subsequent anxiety (Block & Block, 1980; Derryberry & Reed, 1996; Eisenberg, Fabes, Guthrie, & Reiser, 2000). Here, fearful and anxious individuals would not show a deficit in effortful control, but rather equal or higher levels than non-fearful or non-anxious individuals. Importantly, it is not known if fearful temperament leads to higher effortful control, if effortful control feeds into increased temperamental fear, or if fearful temperament and effortful control are orthogonal factors that may work together to increase anxiety.

The overcontrol model is further supported by a parallel line of work that focuses on identifying neural correlates of effortful control (Cavanagh & Shackman, 2015; Henderson et al., 2015). Several neural markers, as measured with the electroencephalogram (EEG) via event-related potential (ERP) components have been related to effortful control. These control-related neural signals are believed to originate in the anterior cingulate cortex (ACC), a region where information about pain, threat, and punishment is integrated to alter future behavior (Shackman et al., 2011). These components are mostly observed in response to novel and conflicting information and the realization of errors (Cavanagh & Shackman, 2015). For instance, conflicting response
options typically found in effortful control tasks (e.g., flanker task) elicit a negative potential, N2, which peaks between 200ms and 350ms after stimulus onset. Another component, the error-related negativity (ERN), is evoked by incorrect responses (e.g., errors of commission), and marked by a negative wave peaking approximately 50ms after an error. Although there are other control-related ERP components (e.g., feedback-related negativity, FRN, or error positivity), this study focuses on the N2 and the ERN as their relation to anxiety has been studied most extensively. Moreover, although theoretically related to AB, the relation between these ERP components (N2 and ERN) and AB is currently unknown. Examining the relation of control-related markers and AB may provide important information about how AB interacts with self-regulatory factors, which in turn would help understand the current inconsistency in AB findings.

The N2 is commonly associated with components of effortful control such as inhibitory control and conflict monitoring (e.g., Falkenstein, Hoormann, & Hohnsbein, 1999; Nieuwenhuis, Yeung, Wildenberg, & Ridderinkhof, 2003). A larger N2 is thought to reflect higher effortful control. For instance, a larger N2 is expected in trials that require inhibition of a prepotent response. Importantly, the N2 has been found in the age range of the present study (5-7 years; Buss, Dennis, Brooker, & Sippel, 2011). A larger N2 has been found in clinically anxious children (Hum, Manassis, & Lewis, 2013), typically developing children high in anxiety (Lamm, Granic, Zelazo, & Lewis, 2011), and temperamentally fearful children (Lamm et al., 2014) compared to non-anxious children. Moreover, two studies have found that N2 magnitude moderates the relation between fearful temperament and anxiety problems (Henderson, 2010; Lamm et al., 2014), such that fearful temperament relates to anxiety more strongly for children with a
large N2. These studies suggest that high levels of N2 activation may be related to over-control and that this may contribute to the stability of fearful temperament and anxiety – in a similar vein as AB is related to anxiety and contributes to the continuity of fearful temperament and its relation to anxiety (Pérez-Edgar et al., 2010, 2011; White et al., 2017).

In the context of AB, the N2 may indicate efforts to divert attention away from threat. This interpretations is consistent with a recent study (Thai, Taber-Thomas, & Pérez-Edgar, 2016) which found that a larger N2 during the dot probe task was related to a smaller bias towards threat or a bias away from threat and that this relation was significantly stronger for highly fearful children. Moreover, training anxious adults to attend away from threat increases the N2 during the dot probe task (Eldar & Bar-Haim, 2010). Evaluating if the N2 as elicited during an effortful control task is also related to AB, would test the specificity of this relation. In other words, if the relation observed between the N2 during the AB task and AB is also observed when the N2 is measured in a (cool) cognitive control task, it would suggest that the N2 acts in a domain-general manner.

The ERN is an ERP component associated with monitoring and detecting errors (Falkenstein, Hohnsbein, Hoormann, & Blanke, 1991; Falkenstein, Hoormann, Christ, & Hohnsbein, 2000; Hajcak, McDonald, & Simons, 2003). Several studies have found heightened error monitoring (as measured by a larger ERN) in anxious individuals compared to non-anxious individuals (Cavanagh & Shackman, 2015; Moser, Moran, Schroder, Donnellan, & Yeung, 2013). Importantly for this investigation, the ERN component has been found in children (Torpey, Hajcak, Kim, Kujawa, & Klein, 2012;
Torpey, Hajcak, & Klein, 2009) as young as 4 years old (Brooker, Buss, & Dennis, 2011), has good psychometric properties in childhood (Meyer, Bress, & Proudfit, 2014), and has been implicated in pediatric anxiety disorders (Meyer et al., 2013; Meyer, Hajcak, Torpey-Newman, Kujawa, & Klein, 2015) as well as temperamental risk for anxiety (Lahat et al., 2014; McDermott et al., 2009). For instance, children high in BI in toddlerhood displayed an increased ERN at age 7, compared to children low in BI. In addition, BI during toddlerhood predicted social anxiety symptoms at age 9 only for children with a large ERN at age 7 (Lahat et al., 2014). Parallel results have been found in adolescence (McDermott et al., 2009), indicating that BI children who also exhibit augmented error monitoring might be at particular risk for anxiety. It is worth noting that none of the cited pediatric studies find anxiety-related differences in behavioral performance, suggesting that this neural marker has greater sensitivity to detect anxiety-related differences compared to behavioral data alone.

Weinberg and colleagues (2012) suggest that errors represent internal signals of potential threat, and that variability in error monitoring may characterize individual differences in threat sensitivity (Weinberg et al., 2012). Given that both AB and error monitoring are established markers for anxiety based on threat processing, a relation between the two could be expected. However, to our knowledge, this relation has not been directly tested. In an indirect test of this relation, a study with adults found that ABMT (training individuals to disengage from threat) was associated with less error monitoring as indexed by the ERN (B. D. Nelson, Jackson, Amir, & Hajcak, 2015) – suggesting a relation between AB and error monitoring. However, this study used a between-subjects design and did not measure anxiety, changes in the ERN, or baseline
AB; thus, it is difficult to interpret the relation between AB and error monitoring (e.g., is error monitoring a mechanism or an outcome of attention bias change?).

**Current Study**

In sum, the data regarding relations between AB, effortful control, and fearful temperament are inconclusive. Some theoretical models and empirical findings suggest that high levels of effortful control act as a protective factor, while others suggest it serves as a risk factor. To our knowledge, all previous studies examining the relation between effortful control and AB have measured effortful control via parental- or self-reports (Cole et al., 2016; Lonigan & Vasey, 2009; Susa et al., 2014, 2012). Importantly, all studies use the “protective factor” model as their framework and most provide support for this model. Directly building on this work, we examined the relation between AB and parent-report of effortful control. We hypothesized that (H1) the relation between AB and fearful temperament would be moderated by parent-reported effortful control, such that AB relates to fearful temperament only at low levels of parent-reported effortful control (Lonigan et al., 2004).

To our knowledge, no study has used behavioral or neural measures of effortful control to examine its relation with AB – even though these measures have also been implicated in the development and maintenance of anxiety, temperament, and anxiety risk. The present study aimed to expand on the current literature and fill this gap by evaluating the relations between AB and behavioral and neural measures of effortful control in a flanker task. However, based on the empirical evidence behind the “risk factor” model and some indirect evidence relating error monitoring and AB (B. D. Nelson et al., 2015), we would expect to find support for the “risk factor” model. In line
with this model, we expect fearful children to display higher effortful control as measured by behavioral (H2) as well as neural (N2/H3 and ERN/H4) measures, compared to non-fearful children. We will also explore if behavioral measures of effortful control moderate or mediate the link between fearful temperament and AB (H2). Finally, we will examine the relation between neural markers of effortful control, AB, and fearful temperament. We will explore the relation of these markers, N2 (H3) and ERN (H4), with AB and fearful temperament, hypothesizing that larger amplitude in these markers is related to higher AB and fearful temperament. We will also examine if these markers moderate or mediate the relation between fearful temperament and AB.

    We also explored if the different measures of effortful control moderated or mediated the relation between fearful temperament and anxiety. Following the work described above, we predicted the following: (H5) parent reported effortful control would serve as a protective factor, (H6) behavioral effortful control would serve as a risk factor, and both neural markers of effortful control, the N2 (H7) and the ERN (H8), would function as a risk factor. Finally, given that most studies involving fearful temperament and AB find that fearful temperament and AB interact to predict anxiety (Cole et al., 2016; Pérez-Edgar et al., 2010, 2011; White et al., 2017), (H9) we also examined if this relation was present in this sample.
Methods

Participants

The sample consisted of 83 5-7 year olds (43 boys; Mean \text{age}=71.42 \text{ months}; SD=8.8; Range \text{age}= 60.03-92.83 \text{ months}). Families were recruited through a university database of families interested in participating in research studies, community outreach, and word-of-mouth. Parents and children provided written consent/assent and the Institutional Review Board approved this study.

Measures

**Fearful temperament.** The BIQ (Bishop et al., 2003) was used to measure children’s fearful temperament. The BIQ is a 30-item measure assessing the frequency of BI-linked behavior in the domains of social and situational novelty on a seven-point scale from 1 (“hardly ever”) to 7 (“almost always”). The questionnaire has adequate internal consistency and validity in differentiating BI from BN children (Bishop et al., 2003), parent-reports on the BIQ correlate with laboratory observations of BI (Dyson et al., 2011), and has been used in prior work to characterize children’s temperament (Clauss, Benningfield, Rao, & Blackford, 2016; Fu, Taber-Thomas, & Pérez-Edgar, 2015; Morales, Taber-Thomas, et al., 2016). The BIQ had good internal consistency in the current study (\( \alpha=.948 \)).

**Anxiety.** The Anxiety scale from the Child Behavior Checklist (CBCL) was used to measure anxiety levels (Achenbach, 1991). In the CBCL, parents rate children’s
behavior in the last two months on a 3-point scale from 0 (not true) to 2 (very true or often true). Anxiety levels were determined by the total sum of the six DSM anxiety items ($\alpha=.690$). The items include statements like “fears going to school” or “nervous, high strung, or tense.”

**Parent-reported effortful control.** The Effortful Control Factor of the Children’s Behavior Questionnaire (CBQ) was used to measure children’s effortful control. The CBQ is a well-validated and widely used questionnaire of child temperament (3- to 7-year-olds; Rothbart, Ahadi, Hershey, & Fisher, 2001). The Effortful Control Factor is composed of four scales (Attentional Focusing, Inhibitory Control, Low-Intensity Pleasure, and Perceptual Sensitivity) with scores averaged to calculate the effortful control score ($\alpha=.771$). In this measure, the caregiver is asked to indicate in 7-point Likert scale ranging from 1 (“extremely untrue of your child”) to 7 (“extremely true of your child”) how well each statement describes their child’s reaction to a given situation in the past 6 months. The scales include items such as “when drawing or coloring in a book, shows strong concentration” or “can easily stop an activity when she/he is told no.”

**Behavioral effortful control.** Behavioral indices during the Flanker task (Eriksen & Eriksen, 1974) were used to measure effortful control. Participants first completed 10 practice trials. The task has 96 trials. In each trial a fixation appears for 500ms followed by a 140ms-blank screen, and then a 700ms target (5 fish presented horizontally). The fish targets point either left or right (equally divided across trials). The central fish is either congruent or incongruent with the direction of the flanking fish (50% incongruent trials). Participants have to indicate the direction of the central fish as quickly and accurately as possible by pressing a button. Participants were allowed to respond for
2000ms (1300ms after the fish disappeared). After the fish, a blank screen appeared for 740ms. Next, feedback appeared for 850ms with a happy emoticon to indicate a correct response (positive feedback) or a sad emotion to indicate an incorrect response (negative feedback). Finally a blank screen appeared for 190ms.

Trials with RTs of less 150ms or more than 2000ms were removed before analyses. Behavioral indicators of effortful control were accuracy and RTs per condition (congruent vs. incongruent). The traditional Flanker effect is calculated via a difference score calculated as the average RT for incongruent trials minus the average RT for congruent trials, in which a larger value indicates a higher cost associated with incongruent trials compared to congruent trials or lower effortful control. Although a simple and commonly used measure, the traditional Flanker effect only uses RTs, ignoring accuracy; thus, meaningful differences in accuracy and speed-accuracy trade-off can go undetected. Recently, an alternative scoring method has been proposed, in which both RT and accuracy are combined into a single bin score that has shown to have increased validity and reliability (Draheim, Hicks, & Engle, 2016; M. M. Hughes, Linck, Bowles, Koeth, & Bunting, 2014). The bin score is calculated following steps (from Draheim et al., 2016):

1) Mean RTs on accurate congruent trials are calculated for each participant.

2) The mean RT from Step 1 is subtracted from the RT for each participant’s individual accurate incongruent trial. This procedure results in every accurate incongruent trial having a score that represents how fast the participant responded on that particular trial relative to his or her own average congruent RT. This is a within-participant comparison done for each participant.
3) The scores from Step 2 for all participants combined are rank ordered into 
deciles and assigned a bin value ranging from 1 to 10.

4) Inaccurate incongruent trials are assigned a bin value of 5, regardless of RT.
   Note that this penalty value is different as the one used for adults (20) because 
   children make considerably more errors than adults.

5) A single bin score is computed for each child by summing all of his or her 
   respective bin values.

As a combination of RTs and accuracy, a higher Flanker bin score indicates two 
things: first, that on incongruent trials, the child’s RT was substantially larger than his or 
her mean RT for congruent trials (i.e., higher cost for incongruent trials; closely related to 
the traditional Flanker effect) in comparison to those of other children; Second, that the 
child made more errors on incongruent trials than other children.

**Psychophysiological measures of effortful control.**

*Psychophysiological recording.* Electroencephalogram (EEG) activity was 
continuously recorded during the Flanker task using a 128-channel geodesic sensor net 
(Electrical Geodesics Inc., Eugene, Oregon). Data from each channel was digitized at a 
1000 Hz sampling rate. EEG channels were collected with reference to Cz and, re-
referenced offline to the average of the mastoids. Vertical eye movements were recorded 
from electrodes placed approximately 1 cm above and below each eye. Horizontal eye 
movements were monitored with electrodes placed approximately 1 cm at the outer 
canthi of each eye. Impedances were kept below 50 kΩ.

Offline, all data preparation and processing were conducted using Brain Vision 
Analyzer (Brain Products GmbH, Germany). Data were filtered with a high-pass
frequency of 0.1 Hz, a low-pass frequency of 40 Hz, and a 60 Hz notch filter. Ocular artifacts from eye blinks and horizontal eye movements were corrected using the method developed by Gratton (Gratton, Coles, & Donchin, 1983). Data were also visually inspected for any remaining artifacts. ERP averages were then created separately for each condition of interest (congruent and incongruent for N2 and correct and error trials for ERN) and were baseline corrected by subtracting from each data point the average activity in a window -100 to the start of the trial for N2 or -300 to -500ms prior to the response (Meyer et al., 2013). Only trials used in the behavioral analyses (see above) will be used in the ERP averages.

**N2.** Based on previous research (Buss et al., 2011; Henderson, 2010), data were segmented and time-locked to the target (the fish) into epochs from 100ms before to 500ms after stimulus presentation. The N2 was defined as the average voltage in the window between 280 and 400ms. As illustrated in Figure 1, we evaluated the N2 along the midline by creating a composite of electrodes for frontal (4, 5, 10, 11/Fz, 12, 16, 18, and 19), central (7, 31, 55, 80, 106, and 129/Cz), and posterior sites (61, 62/Pz, 67, 72, 77, and 78). The grand mean waveforms were inspected to ensure that the N2 is captured in those electrode sites and time window. We evaluated the difference score between congruent and incongruent trials (i.e., ΔN2) for parsimony (Buss et al., 2011).

**ERN.** Consistent with previous studies (e.g., Meyer et al., 2013; Torpey et al., 2012), the brain responses following errors (i.e., ERN) as well as correct responses (i.e., correct-related negativity; CRN) were evaluated along the midline (same electrode composites as N2; Figure 1) and were defined as the average voltage in the window from -50 prior the response to 100ms after the response. The ERN can be calculated by either
averaging only the error-trial waveform or by subtracting the correct-trial waveform from the error-trial waveform (i.e., ΔERN) (Pailing, Segalowitz, Dywan, & Davies, 2002). We evaluated the ΔERN for parsimony.

Attention bias to threat. Attention bias to threat was measured by the dot probe task. The task consists of 8 practice trials and 100 experimental trials randomly presented in four blocks of 25 trials. Each trial begins with the presentation of a central fixation cross for 500ms followed by a pair of faces presented side-by-side for 500ms. One of the faces is replaced by an asterisk, which appears for 2500ms. Using a computer mouse,
children are asked to indicate, as quickly and accurately as possible, the side of the screen the asterisk appears. The inter-trial interval is 1800ms. Children seat approximately 60 cm from a 20 in. LCD color monitor. Stimuli are presented with E-Prime 2.0.

Three combinations of faces are presented: Angry-Neutral (40 trials), Happy-Neutral (40 trials), and Neutral-Neutral (20 trials). Ten different actors (5 male) are used from the NimStim face stimulus set (Tottenham et al., 2009). Each face is presented ten times. Congruent trials were those in which the probe replaced the affective face (i.e., angry or happy). Incongruent trials are those in which the probe replaces the neutral face. Response accuracy and reaction times are recorded for each trial.

Incorrect dot-probe trials or trials with RTs of less 150ms or more than 2000ms were removed before analyses. In addition, trials that have responses with RTs +/- 2.5 SDs from an individual’s mean were removed. AB scores to the emotional faces were calculated by subtracting the mean RT for congruent trials from the mean RT for incongruent trials. Positive values denote a bias to the emotional stimuli whereas negative scores indicate bias away of the emotional stimuli.

Statistical Analyses

To examine the relations between fearful temperament, AB towards threat, and effortful control, we employed zero-order correlations. We then evaluated if the relation between fearful temperament and AB is mediated or moderated by the different measures of effortful control. To do that, in line with previous studies (Cole et al., 2016; Morales et al., 2015; Pérez-Edgar et al., 2010, 2011), we used a moderated mediation model (Figure
2) based on the work of Preacher, Rucker, and Hayes (2007). This analysis provides the same information as a traditional regression model, while allowing us to simultaneously examine both the moderation and mediation relations. We will run a total of four models (H1-H4), one for each of the effortful control measures: parent report, behavioral, and psychophysiological (N2 and ERN).

![Diagram](image)

**Figure 4-2:** Example of moderated mediation model (Preacher et al., 2007).

In addition, to evaluate if the different measures of effortful control mediated or moderated the relation between fearful temperament and anxiety (H5-H8), we employed the same moderated mediation model (Figure 2; Preacher et al., 2007) for each effortful control measure, but with anxiety as the outcome. Finally, to evaluate if AB moderated or mediated the relation between fearful temperament and anxiety, the same moderated mediation model (Figure 2; Preacher et al., 2007) was used but with AB as the mediator/moderator and anxiety as the outcome.

Of the 83 children who participated, 79 attempted the DPB and 80 the flanker (due to computer difficulties). Seventy-one completed the tasks with EEG (i.e., 9 children...
refused to wear the EEG cap). Children who refused to wear the EEG cap did not significantly differ on any of the study measures ($p$'s > .27). Fourteen children were removed from Flanker analyses (behavioral and ERP) due to poor performance (<60% accuracy). Two of those children were also excluded from the dot probe data because of poor accuracy (<75%). These children did not differ in any of the study measures ($p$'s > .12). This left 77 children with attention bias data, 67 with Flanker behavioral data, and 57 children with N2 data. For the ERN and CRN, 22 children did not have the minimum of 6 artifact-free trials to compute an average waveform. Children with less than 6 artifact-free error trials were on average older than children who had more than 6 error trials, $\text{Mean}_{age}=75.50$ vs. 69.98 months, $t(34.94)=-2.53$, $p=.016$.

Finally, all variables were checked for normality and inspected for outliers. Values greater than 2.5 $SD$s from the mean were removed. This lead to one score deleted for threat bias, one for flanker traditional and bin score, one for BI, one for parent-reported effortful control, one for ERN at frontal, central, and posterior sites, and one for N2 at the frontal site.

**Results**

**Descriptive Questionnaire Results**

As shown in Table 1, the only variable significantly related to parent-reported effortful control was gender – where girls were reported as higher in effortful control compared to boys, $t(78)=4.19$, $p<.001$, $d=0.94$. As such, all analyzes examining parent
reports of effortful control were controlled for the effects of gender. As expected, BI was related to anxiety, $r(74)=.40, p<.001$. 
Table 4-1: Means, standard deviations, and correlations

<table>
<thead>
<tr>
<th>Variable</th>
<th>$M$</th>
<th>$SD$</th>
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<tbody>
<tr>
<td>1. Gender</td>
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<td>2. Age</td>
<td>71.42</td>
<td>8.80</td>
<td>.10</td>
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<tr>
<td>3. Threat Bias</td>
<td>12.17</td>
<td>59.96</td>
<td>-0.08</td>
<td>-0.03</td>
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<td>4. Flanker Bin Score</td>
<td>246.03</td>
<td>28.03</td>
<td>.23*</td>
<td>.31*</td>
<td>-0.07</td>
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<td>5. CBQ Effortful Control</td>
<td>5.31</td>
<td>0.73</td>
<td>.43*</td>
<td>.05</td>
<td>-0.07</td>
<td>.01</td>
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<tr>
<td>6. Behavioral Inhibition</td>
<td>86.10</td>
<td>25.63</td>
<td>.13</td>
<td>-.10</td>
<td>-.19*</td>
<td>.21</td>
<td>-.15</td>
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<td>7. Anxiety</td>
<td>1.32</td>
<td>1.50</td>
<td>-.07</td>
<td>-.14</td>
<td>.10</td>
<td>-.16</td>
<td>.01</td>
<td>.40*</td>
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<td>8. N2 Frontal</td>
<td>0.57</td>
<td>6.51</td>
<td>.13</td>
<td>.16</td>
<td>.21</td>
<td>.10</td>
<td>.14</td>
<td>-.17</td>
<td>-.14</td>
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<td>9. N2 Central</td>
<td>1.15</td>
<td>5.33</td>
<td>.09</td>
<td>.09</td>
<td>.16</td>
<td>.16</td>
<td>-.22*</td>
<td>-.20</td>
<td>.75*</td>
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<tr>
<td>10. ERN Frontal</td>
<td>-1.59</td>
<td>4.95</td>
<td>-.15</td>
<td>-.22</td>
<td>.10</td>
<td>-.14</td>
<td>-.08</td>
<td>.03</td>
<td>.20</td>
<td>.27</td>
<td>.11</td>
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<tr>
<td>11. ERN Central</td>
<td>1.47</td>
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<td>-.21</td>
<td>-.32*</td>
<td>.45*</td>
<td>-.04</td>
<td>.12</td>
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<td>.27</td>
<td>.18</td>
<td>.21</td>
<td>.38*</td>
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<tr>
<td>12. ERN Posterior</td>
<td>2.38</td>
<td>5.62</td>
<td>-.27</td>
<td>-.13</td>
<td>.32*</td>
<td>-.06</td>
<td>.10</td>
<td>-.11</td>
<td>.18</td>
<td>.16</td>
<td>.32*</td>
<td>.25</td>
<td>.86*</td>
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</tbody>
</table>

Note. * indicates $p < .05$. † indicates $p < .10$. $M$ and $SD$ are used to represent mean and standard deviation, respectively. Boys were coded as 0 and girls as 1.
Descriptive Behavioral Results

Flanker Task

Behavioral results suggested that, as expected, there was a Flanker effect, in which children were faster for congruent trials than incongruent trials, $t(64) = 7.61, p<.001, d=0.944$. This difference, or the Flanker effect, was on average 49.98ms. The Flanker effect was related to the age of the child, $r(63)=.25, p=.045$. Moreover, as expected, older children made fewer errors during the Flanker task, $r(65)=-.44, p<.001$. Finally, as shown in Table 1, the Flanker bin score was also related to age, $r(64)=.31, p=.011$. As such, all analyses with the behavioral Flanker scores controlled for age. As the Flanker bin score integrates both RT and accuracy of performance and has been shown to be a more valid indicator of performance and have better psychometrics than the traditional difference score (Draheim et al., 2016; M. M. Hughes et al., 2014), the Flanker bin score was used in subsequent analyses.

Dot Probe Task

There was no significant bias effect towards threat, $t(75) = 1.77, p=.081$, $d=0.203$, and as shown in Table 1, attention bias did not directly relate to any of the other variables.
Descriptive ERP Results

**N2**

After inspecting the grand average waves (Figure 3), it was determined that there was an N2-like component at the frontal and central sites. A 2x2 repeated measures ANOVA model evaluated if there was an effect of condition (Congruent and Incongruent) and site (Frontal and Central) as well as an interaction condition by site. The model revealed no significant effect for condition, site, or their interaction (all \( p \)'s > .121, \( \eta^2 < .049 \)).

Figure 4-3: Waveforms represent the N2 component for congruent and incongruent trials as well as their difference score (incongruent – congruent) at frontal (A), central (B), and
After inspecting the grand average waves (Figure 4), it was determined that there was an ERN-like component at the frontal and central sites. A 2x3 mixed-effects model evaluated if there was an effect of condition (Correct and Error) and site (Frontal, Central, and Posterior) as well as an interaction of condition by site. The model revealed a significant main effect of site, $F(2, 62) = 10.92, \ p < .001, \eta^2 = .261$, in which the posterior site was significantly more negative than the frontal, $t(33)=2.80, \ p = .008, d=0.481$, and central sites, $t(34)= 4.58, \ p < .001, \ d = 0.86$, regardless of condition. This effect was subsumed under a significant site by condition interaction, $F(2, 41.56) = 10.27, \ p = .001, \eta^2 = .249$, in which error trials elicited a larger (more negative) ERN than correct trials only at the frontal site, $t(32)= 2.06, \ p = .047, \ d = 0.36$. However, the opposite was true at the posterior site, $t(33)= 2.48, \ p = .018, \ d = 0.43$. As illustrated in Figure 3 by the difference wave, it suggests that the ERN was most evident in the frontal and central sites – although it was only significant in the frontal site. As such, future analyses focus on these two sites.
Analyses Predicting Attention Bias

**H1: Parent-Reported Effortful Control, BI, and Attention Bias**

The model evaluating if parent-reported effortful control moderated the relation between BI and attention bias revealed that, while controlling for gender, BI was related to lower effortful control, $\beta = -0.006, p = .038$. The effect of effortful control on attention
bias was not significant, nor the interaction between BI and effortful control to predict attention bias.

**H2: Behavioral Effortful Control, BI, and Attention Bias**

The model testing if behavioral effortful control, Flanker bin score, moderated or mediated the relation between BI and attention bias revealed that, while controlling for age, BI was related to a higher Flanker bin score, $\beta = 0.28, p = .040$. In addition, BI was related to attention bias away from threat, $\beta = -0.71, p = .028$. Neither the effect of behavioral effortful control nor its interaction with BI was significantly related to attention bias.

**H3: N2, BI, and Attention Bias**

The model testing if effortful control as indexed by the N2 component moderated or mediated the BI-attention bias relation revealed no significant effects at either the frontal or central sites. There was only a marginal relation between BI and N2 at the central site, $\beta = -0.05, p = .096$, such that BI was related to a larger (more negative) N2.

**H4: ERN, BI, and Attention Bias**

As shown in Figure 5, the model testing if effortful control as indexed by the ERN component moderated or mediated the BI-attention bias link revealed that a smaller ERN
at the central site was related to attention bias towards threat, $\beta = 5.02, p = .009$. No other effects were significant in this model.

![Figure 4-5: Threat bias as a function of the ERN difference score at the central site.](image)

**Analyses Predicting Anxiety**

**H5: Parent-Reported Effortful Control, BI, and Anxiety**

The model evaluating if parent-reported effortful control moderated or mediated the relation between BI and anxiety revealed that, while controlling for gender, BI was the only significant predictor of anxiety, $\beta = 0.026, p < .001$. 
**H6: Behavioral Effortful Control, BI, and Anxiety**

The model evaluating if behavioral effortful control as measured by the Flanker bin score moderated or mediated the BI–anxiety relation revealed that, while controlling for age, BI was the only significant predictor of anxiety, $\beta = 0.027$, $p < .001$. However, the main effect of behavioral effortful control on anxiety was marginally significant, $\beta = -0.014$, $p = .061$; such that, after accounting for the effects of age and BI, better behavioral effortful control related to more anxiety.

**H7: N2, BI, and Anxiety**

The model evaluating if the N2 component at the frontal and central sites moderated or mediated the BI–anxiety link revealed that BI was significantly related to anxiety, $\beta = 0.021$, $p = .008$. However, the main effect of BI was qualified by a significant interaction with the N2 at the frontal site, $\beta = 0.002$, $p = .045$. As depicted in Figure 6, probing this interaction revealed that BI was related to anxiety only for children who displayed a small N2 (+1 SD) at the frontal site, $b = 0.037$, $p < .001$. BI was not related to anxiety for children who displayed a large N2 (-1 SD), $b = 0.004$, $p = .724$. 
The model evaluating if the ERN component at the central and posterior sites moderated or mediated the relation between BI and anxiety revealed no significant effects. However, BI was marginally related to anxiety, $\beta = 0.021, p = .062$. Moreover, while accounting for BI, there was a trending effect for a smaller ERN related to more anxiety, $\beta = 0.084, p = .105$.

**H8: ERN, BI, and Anxiety**

Figure 4-6: Anxiety as a function of behavioral inhibition and N2 at the posterior site. Large N2 was defined as 1 SD below the mean and small N2 as 1 SD above the mean.
**H9: Threat Bias, BI, and Anxiety**

The model evaluating if attention bias to threat moderated the relation between BI and anxiety revealed that BI was the only significant predictor of anxiety, $\beta = 0.031$, $p = .002$. Nevertheless, the main effect of attention bias on anxiety was marginally significant, $\beta = 0.006$, $p = .058$, such that, after accounting for the effect of BI, attention bias to threat related to higher levels of anxiety.

**Discussion**

Current data on the relations between AB, effortful control, and fearful temperament are inconclusive as some suggest that effortful control serves as a protective factor, while others propose that it acts as a risk factor. The present study aimed to clarify the role of effortful control in the relations between fearful temperament, AB, and anxiety by using a multi-method approach. Results largely supported the model in which effortful control serves as a protective factor rather than a risk factor. However, not all results supported our systematic set of hypotheses.

The analyses utilizing parent reports (H1) and behavioral (H2) measures of effortful control revealed largely consistent results, in which fearful temperament was negatively related to both measures effortful control. This is in line with the protective factor model, where high levels of fearful temperament (mostly measured as negative affectivity) are related to lower levels of effortful control (Ahadi, Rothbart, & Ye, 1993; Rothbart, Ahadi, Hershey, & Fisher, 2001). However, neither measure of effortful control mediated or moderated the relation between fearful temperament and anxiety (H5 & H6).
This does not support the protective factor model, because we expected that fearful temperament would only relate to anxiety at low levels of effortful control (Lonigan et al., 2004). Moreover, neither parental reports nor behavioral measures of effortful control moderated or mediated the relation between fearful temperament and AB (H1 & H2). This is in line with Cole et al. (2016), in which parent-reported effortful control did not mediate or moderate the relation between fearful temperament and AB in a sample of young children (4-7 years). Findings with older children (9-18 years) indicated that self-reports of effortful control moderate the relation between temperament and AB (Lonigan & Vasey, 2009; Susa et al., 2014). Cole et al. (2016) suggest this may be because children’s effortful control capacities at this young age are limited or immature. The findings of this study support that interpretation given that behavioral measures of effortful control also failed to moderate the relation between temperament and anxiety. However, a true test of that interpretation would require testing the moderation in younger and older children within the same study.

For the analyses using the N2 as an index of effortful control (H3), there were no significant relations between the N2, fearful temperament, and AB. However, fearful temperament was marginally related to a larger N2 component. This is in line with a previous study, which show BI related to a larger N2 (Lamm et al., 2014). Moreover, as in previous studies (Henderson, 2010; Lamm et al., 2014), findings revealed that the N2 moderated the relation between fearful temperament and anxiety (H7). However, in the current study, fearful temperament only related to anxiety for children who displayed a small N2. In contrast, previous studies found that the temperament-anxiety link was present only for children who displayed a large N2 (Henderson, 2010; Lamm et al.,
2014). There are important differences between studies, making them difficult to compare. For instance, Lamm et al. (2014) measured temperament in toddlerhood (2-3 years) as a composite of behavioral and parent reports and assessed the N2 and anxiety later in childhood (7 years). Henderson (2010) evaluated all relations concurrently in a sample of 9-13 year olds. Our current findings, together with results from parent reports and behavioral measures of effortful control discussed above, support the protective factor model.

The analyses with the ERN (H4), showed the hypothesized relation between ERN and AB. However, this relation was in the opposite direction, in which a smaller ERN was related to higher AB. This is contrary to a previous study with adults where training AB away from threat reduced the ERN (B. D. Nelson et al., 2015). Our findings are in line with recent set of studies in the ERN-anxiety literature that suggest that the relation between anxiety and the ERN is moderated by age. Studies examining the relation in older children (>8 years; average ages 13.3, 10.2, and 11.4 years) find that larger ERN is related to higher levels of anxiety, akin to the adult literature (Hajcak, Franklin, Foa, & Simons, 2008; Ladouceur, Dahl, Birmaher, Axelson, & Ryan, 2006; Meyer, Weinberg, Klein, & Hajcak, 2012). In contrast, studies with younger children (<9 years; average ages 7.02, 6.00, 6.14) find the opposite relation, in which a smaller ERN is related to higher anxiety levels and anxiety-related markers (Lo et al., 2016; Lo, Schroder, Moran, Durbin, & Moser, 2015; Meyer et al., 2012; Torpey et al., 2013). Moreover, Meyer et al. (2012) in a sample of 8-13 year-old children, found that the relation between ERN and anxiety was moderated by age, such that a larger ERN was related to higher levels of anxiety for older children (12.43 years). Among younger children (9.47 years), they
found that a smaller ERN was marginally related to higher levels of anxiety. Together, these findings suggest that the relation between ERN and anxiety changes during development, potentially reversing directions around age 9-10.

These opposing patterns across childhood and into adolescence may reflect the structural and functional development of the ACC. For instance, other work examining the development of emotion regulation using fMRI connectivity analyses suggest that the connectivity between anterior brain areas (i.e., mPFC) and the amygdala change considerably with age – where mPFC-amygdala connectivity shifts from positive to negative connectivity to resemble an adult-like pattern around age 9-10 years (Gee et al., 2013). This would suggest that the ERN develops as a form of top-down emotion regulation, providing support for the protective factor model.

The current results support the interpretation of the ERN as a marker of threat sensitivity (Weinberg et al., 2012). However, it is possible that the relation between the ERN and AB reverses during development to the hypothesized relation. Moreover, we found no evidence of an interaction with fearful temperament (H4). Similarly, the ERN did not moderate or mediate the relation between BI and anxiety (H8). This is in contrast with previous studies, which have found a direct relation between fearful temperament and ERN (Lahat et al., 2014; McDermott et al., 2009). It is worth noting, as with the N2, these samples are not perfectly comparable as previous studies measured fearful temperament based on a combination of behavioral observations and parent reports early in childhood (1 year to 7 years) and evaluated the relation with ERN and anxiety longitudinally (7-9 years and 15 years; Lahat et al., 2014; McDermott et al., 2009, respectively). It is possible that the current study’s measure of temperament (parent
report) does not capture the relations between BI, ERN, and anxiety this early in childhood. However, results revealed that after controlling for temperament, there was a relation between smaller ERN and higher levels of anxiety. This result, although marginally significant, provides further support for to the growing literature that suggests that in early childhood a smaller ERN, rather than a larger ERN, is related to higher levels of anxiety. Furthermore, this result is in line with the protective factor model. That is, children with a small ERN, lower effortful control, display a bias towards threat and tended to have higher levels of anxiety.

The lack of a direct effect of BI on AB is not as unexpected given that almost all of the BI studies fail to find a relation between BI and AB (Cole et al., 2016; Pérez-Edgar et al., 2011; White et al., 2017). However, these studies find that AB moderates the relation between fearful temperament and anxiety, such that only fearful children with an attention bias towards threat display high levels of social withdrawal and anxiety (Cole et al., 2016; Pérez-Edgar et al., 2011; White et al., 2017). As such, we also evaluated this relation in the current study (H9). However, this moderated relation was not present in the current sample. This unexpected finding may be due to the truncated range of fearful temperament and anxiety in the current study. For instance, using the cutoff used to characterize children as BI in previous studies using the BIQ (e.g., Fu et al., 2015; Morales, Taber-Thomas, et al., 2016), the current sample would only have 10 high BI children (~12%).

Interestingly, after accounting for the considerable amount of variance of BI on anxiety, anxiety was marginally predicted by behavioral effortful control measures as expected by the risk factor model. Moreover, while controlling for BI, AB related to
higher levels of anxiety. This suggests that the unexplained variance of anxiety, after taking into account the normative effects of temperament, related in the expected direction to known markers of anxiety. It is possible that if the sample contained more variance in anxiety, particularly in the clinical range, results would have supported the risk factor model as suggested by other studies. Future studies should examine the relation between fearful temperament, AB, anxiety, and several measures of effortful control in a clinical sample.

When interpreting the findings of this study, it is important to consider some additional limitations. First, the present study uses a small sample size, which was additionally reduced by including children with artifact-free EEG data and good performance across several tasks. Although a considerable amount of data was lost for some analyses, especially the response-locked ERP analyses, the amount of data loss in the current study is similar to other ERN studies with young children (Lo et al., 2015). Second, the current study only examines cross-sectional associations, precluding analyses across development. Future studies should examine the cross-task relations evaluated in this study across development. Of special interest is how the relations examined in this study change from childhood into adolescence. The current findings along with the literature reviewed suggest that there might be considerable changes in the relations between effortful control, AB, fearful temperament, and anxiety during the development of executive processes.
**Conclusion**

In sum, this study evaluated the function of effortful control in the relations between AB, fearful temperament, and anxiety by using a multiple measures of effortful control. In general, results from parent reports, behavioral measures, and neural markers supported the model in which effortful control serves as a protective factor rather than a risk factor. Moreover, this study found for the first time that attention bias to threat was directly related to the ERN, providing further support for the relation between neural responses to errors and AB. Overall, the current findings help clarify the complex role of effortful control in the links between AB, fearful temperament, and anxiety, and raise important questions for future investigations. A better understanding of the function of effortful control on these relations is crucial to clarifying the utility of AB as a marker of anxiety as well as potential AB-based treatments of anxiety across development.
Chapter 5

General Discussion

The aim of each of the three studies in the present dissertation was to expand our understanding of the development of AB and its relation with anxiety. This was done by studying several outstanding issues in the AB literature. The first aim was to study AB and its relation to anxiety from a developmental perspective. Secondly, the present dissertation investigated the mechanisms of AB by using several methods. Namely, we employed multiple tasks, measured eye movement, assessed neural correlates, and evaluated the impact of a theoretically relevant cognitive process (i.e., effortful control).

To briefly summarize each study and their findings, in the first study (Morales, Taber-Thomas, et al., 2016), we examined patterns of AB across two related AB measures in a sample of 9-12 year olds. In addition, we tested if the relation among AB measures varied across BI and if specific patterns of attention across tasks are associated with anxiety. We found that BI was not associated with performance in the dot-probe task, but was associated with increased attentional bias to threat in the affective Posner task. Cross-task convergence was dependent on temperament, such that attention bias was related across the two tasks only in behaviorally inhibited children. Finally, children who were consistently biased across tasks (showing high or low attentional bias scores in both tasks, rather than high in one but low in the other) had higher levels of anxiety. These findings suggest that convergence across attention bias measures may be
dependent on individuals’ predispositions (e.g., temperament). Moreover, convergence of attention bias across measures may be a stronger marker of information processing patterns that shape socioemotional outcomes than performance in a single task.

In the second study (Morales, Brown, Taber-Thomas, LoBue, Buss, & Pérez-Edgar, 2017), we measured AB by examining eye movements in infants (4 to 24 months) during a task that captures disengagement from emotional stimuli. We looked to see if AB towards threat is associated with known risk factors for anxiety, such as maternal anxiety and fearful temperament. We found that AB to the affective faces did not change with age, and that it is not related to fearful temperament. However, AB to threat, but not AB towards reward (happy faces), is positively related to maternal anxiety, such that higher maternal anxiety predicts a larger AB for all of the infants.

In the third study (Morales, Buss, & Pérez-Edgar, in prep), we examined the role of effortful control as evaluated by several measures in the relations between AB, fearful temperament, and anxiety in children (5 to 7 years). We found that, across several measures, effortful control mostly acted as a protective factor, as opposed to a risk factor, such that higher effortful control as reported by parents and based on children’s behavior was related to lower levels of fearful temperament (i.e., BI). Moreover, neural markers of effortful control revealed similar patterns, in which lower effortful control (i.e., smaller ERN) was related to higher AB and marginally to higher levels of anxiety. Moreover, only for children with low effortful control (i.e., smaller N2), fearful temperament was positively related to anxiety.

Together, the findings from the current dissertation suggest that: 1) it is important to consider cross-task AB convergence as this may index important individual
characteristics such as fearful temperament and/or anxiety; 2) AB can be captured during infancy and that meaningful individual differences in AB exist from early in development such as relations with known risk factors for anxiety; 3) other cognitive functions like effortful control likely play an important role in the relations between AB, fearful temperament, and anxiety. More specifically, that at least early in childhood, effortful control likely serves as a protective factor rather than a risk factor.

To address the first outstanding issue, namely that most empirical investigations and theoretical models of AB lack a developmental perspective (Field & Lester, 2010a), all studies took a developmental perspective. Because anxiety problems originate early in childhood (Pine, 1998; Pine & Fox, 2015), this developmental period presents a window of opportunity for early intervention and prevention. Economically, it is likely that early interventions are more cost effective than interventions later in development (Heckman, 2000). In addition to stopping anxiety problems before they become a disorder, early interventions may avoid some of the developmental sequelae of early anxiety problems, such as fewer friends (Harrist, Zaia, Bates, Dodge, & Pettit, 1997; Rubin, Coplan, & Bowker, 2009), academic problems (A. A. Hughes, Lourea-Waddell, & Kendall, 2008; Ialongo, Edelsohn, Werthamer-Larsson, Crockett, & Kellam, 1995), and substance abuse (Deas-Nesmith, Brady, & Campbell, 1998; Hicks, Durbin, Blonigen, Iacono, & McGue, 2012; Kendall, Safford, Flannery-Schroeder, & Webb, 2004; Kessler et al., 1996). However, the number of effective interventions for anxiety during early childhood is scarce (Bayer et al., 2009). Part of the challenge is that most anxiety treatments (e.g., cognitive behavioral therapy) used with adults and youths are not amenable as preventive interventions with young children. As such, most successful preventive interventions
have focused on teaching parents strategies on how to parent temperamentally fearful children (e.g., Rapee, 2013; Rapee, Kennedy, Ingram, Edwards, & Sweeney, 2010). An additional issue is our difficulty in identifying which children are at risk, as even the best early predictors are only ~40% accurate (e.g., Clauss & Blackford, 2012). AB has the potential to aid both issues by being an early marker of anxiety risk as well as a preventive intervention that can be done early in development. AB-based interventions are believed to work by changing individuals’ implicit biases in attention and information processing. As such, they may not require higher cognitive capacities such as language or awareness of thoughts and behaviors. In addition, AB-based interventions have the potential to be of low cost and high scalability. Finally, there is preliminary evidence to suggest that they are effective in children (e.g., Eldar, Ricon, & Bar-Haim, 2008). However, in order to effectively use AB as a marker of anxiety risk and/or as a preventive intervention, we need a better understanding of the development of AB.

The three studies in the present dissertation suggest that AB can be captured across development and that there are not significant age differences in AB. However, all studies found that AB varied according to levels of anxiety risk or other anxiety markers. This is in line with a model that suggest that AB does not vary with age, but is moderated by individual-level characteristics such as constitutional and environmental factors (e.g., temperament, Field & Lester, 2010a; Morales, Fu, et al., 2016). If this is the case, AB may be a suitable marker for indexing anxiety risk from very early in development, as suggested by Study 2. However, this conclusion should be interpreted with caution, as none of the three studies used a longitudinal design. Although the three studies covered a wide age range, the main limitation across studies is the cross-sectional nature of the data,
which restricts the developmental inferences that can be drawn from these findings. Prospective longitudinal studies will be needed to test the developmental impact of the current findings.

Another major outstanding issue in the current AB literature is that the mechanisms behind AB are not well understood. This is partly a consequence of measuring AB predominantly with one task, the dot-probe task, which combines several processes such as cue processing, cue disengagement, response speed, and competing approach/avoidance mechanisms (Mogg et al., 2008) – potentially hiding any true signal and leading to inconsistent findings. For instance, several studies have not found the expected relations (Britton et al., 2012, 2013; Gotlib et al., 2004; Pineles & Mineka, 2005; Pishyar et al., 2004; Waters et al., 2004) and other studies find anxiety-linked attentional avoidance or bias away from threat (Brown et al., 2013; Mansell et al., 1999; Monk et al., 2006; Morales et al., 2015; Salum et al., 2013; Stirling et al., 2006; Waters et al., 2014). These contradictory findings heavily limit any clinical application of AB.

However, it is possible that these different findings are not “noise,” but important individual differences in how AB relates to anxiety (Roy et al., 2015) and that a better understanding of the mechanisms that underlie AB can improve our characterization of such individual differences. For instance, Study 1 speaks directly to this issue as there was no relation between AB as traditionally measured and fearful temperament and anxiety. However, when considered along with another AB measure, displaying a consistent bias across measures (towards or away from threat) was related to fearful temperament and anxiety. This suggests that AB can have implications when it is evident across contexts and attention processes. Another example comes from recent studies with
soldiers at risk for PTSD. Soldiers were trained to attend *towards* threat rather than *away* from threat, as PTSD is characterized by a bias *away* from threat. These studies find positive outcomes after attention training towards threat for stress-related symptoms and PTSD prevalence (Wald et al., 2016, 2017). This further suggests that biases toward or away from threat index important differences that may have distinct implications for adaptive functioning. Moreover, these results imply that it is crucial to understand AB patterns before intervening as training all individuals in the same direction may be detrimental rather than beneficial for some individuals.

Using different approaches, all three studies in this dissertation furthered our knowledge of the mechanisms of AB by employing multiple tasks: measuring eye movement, assessing neural correlates, and evaluating the impact of a theoretically relevant cognitive process (i.e., effortful control). Although each of the studies separately informs AB mechanisms, it is a challenge to integrate findings across studies as they mostly use different methods and are done at different ages. An important future step would be a comprehensive study in which the same participants perform multiple tasks while measuring eye movement and neural correlates. Moreover, a comprehensive study would not only evaluate AB and anxiety, but also evaluate the impact of relevant cognitive processes such as effortful control. This would be ideal because it would help to integrate the current findings and inform the mechanisms that underlie AB. For instance, it would be possible to use novel methods that integrate eye tracking and neural correlates as measured by EEG, such as fixation-related potentials (e.g., Kamienkowski, Ison, Quiroga, & Sigman, 2012; Kaunitz et al., 2014). Another important limitation across studies is that temperament was only characterized based on parent reports,
potentially introducing shared method variance. Future studies should characterize temperament based on behavioral observations to avoid this issue.

Despite these limitations, the present dissertation improves our characterization of individual differences in attentional patterns that are related to anxiety by taking a developmental and multi-method approach in an attempt to elucidate core-underlying mechanisms. Increasing our understanding of the relations between AB and anxiety across development will improve our ability to identify early vulnerabilities for anxiety. Furthermore, these findings may allow us to develop therapeutic and/or preventive interventions for anxiety.
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