Fearful Temperament in Middle Childhood and Anxiety Symptoms in Adolescence:

The Roles of Attention Biases, Effortful Control, and Frontal EEG Asymmetry

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ABSTRACT

Fearful temperament represents one of the robust predictors of the development of child and adolescent anxiety. Not all children with fearful temperament unvaryingly develop anxiety, however. Diverse processes resulting from the interplay among attention, cognitive control, and motivational system drive the trajectories toward more adaptive or maladaptive directions. In this study, I examined various factors that underlie the association between fearful temperament at age 9 and adolescent anxiety symptoms including attention biases, different components of effortful control, and frontal EEG asymmetry. 78 children participated in this study. Results indicate that fearful temperament at age 9 significantly predicted adolescent anxiety symptoms. This association, however, was moderated by children’s effortful control and frontal EEG asymmetry at age 9. Specifically, fear at 9 years predicted adolescent anxiety only when children had low attentional control, low inhibitory control, low activation control, and exhibited greater right activation from baseline to task. The associations between AB and fearful temperament as well as anxiety were not significant. The association between fear at 9 years and sustained AB during adolescence, however, was moderated by children’s attentional control, inhibitory control, and frontal EEG asymmetry at age 9. Specifically, fear predicted attention biases away from threat when children had high attentional control, high inhibitory control, and showed greater left activation. The findings will be discussed in terms of the roles of attention biases in the developmental of anxiety and how different components of effortful control and frontal EEG asymmetry contribute to the resilience process.
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GENERAL AUDIENCE ABSTRACT

Anxiety disorders represent one of the most commonly occurring mental health problems in childhood and adolescence. Children who tend to show wariness and distress to negative stimuli are more likely to have anxiety. Not all children with fearful temperament develop anxiety, however. Certain individual characteristics can protect fearful children from having anxiety symptoms. In this study, I examined the roles of attentional biases toward threat (AB), different components of self-regulation (EC), and the asymmetrical frontal brain activation (FA) in changing the relation between fearful temperament and anxiety. 78 children participated in this study. Results indicated that adolescents were at higher risk for anxiety if they showed high fearful temperament at age 9. However, the risk could be attenuated if children were better able to control their attention and behaviors, and exhibited greater left activation from resting to a mildly stressful situation at age 9. In addition, fearful children were better able to direct attention away from threat during adolescence if they were better able to control their attention and behaviors, and exhibited greater left activation from resting to a mildly stressful situation at age 9. The findings provide suggestions for early identification and intervention of children who are more vulnerable to anxiety during adolescence.
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**Introduction**

Anxiety disorders represent one of the most commonly occurring mental health problems in early development, with prevalence estimates ranging from 6.1% to 24% in childhood and 18.6% to 31.9% in adolescence (Briggs-Gowan et al., 2000; Kroes et al., 2001; Merikangas et al., 2010). Anxiety disorders are associated with significant impairments in current and future functioning across different domains (Rapee et al., 2009); thus, examining the risk factors leading to a trajectory of anxiety has gained substantial attention in the past few years.

Temperament is defined as individual differences in emotional reactivity and the self-regulation of that reactivity (Rothbart & Ahadi, 1994). Negative temperament is involved in the etiology of child psychopathology (Muris & Ollendick, 2005; Nigg, 2006). Fearful temperament typically refers to the extent of negative affect, such as worry or uneasiness, in face of potentially threatening or painful situations (Rothbart et al., 2001). Conceptually similar terms in developmental literature that typically used to describe fearful temperament include fear, shyness, behavioral inhibition, and social wariness (e.g., Buss, 2011; Rubin, 2009; White et al., 2011). It is well established that fearful temperament precedes and maintains anxiety problems across childhood and adolescence (see Degnan et al., 2010, for a review). For example, dysregulated fear at age 2 significantly predicts social wariness and anxiety at age 6 (Buss et al., 2013). It is important to note, however, that not all children with fearful temperament develop anxiety disorders. In line with the developmental psychopathology perspective, fearful temperament does not unvaryingly and linearly lead to anxiety (Cicchetti & Rogosch, 2002; Ollendick & Hirshfeld-Becker, 2002), as noted in multiple studies. For example, Rapee (2014) reported that although fearful temperament at age 4 is a significant predictor of social anxiety...
disorder at age 15, only 37% of inhibited children were diagnosed with social anxiety disorder in adolescence.

The modest association between fearful temperament and anxiety (Degnan & Fox, 2007) stresses the importance of examining the potential mechanisms underlying the relation between temperament and anxiety as well as elucidating the factors that could alter such mechanisms, potentially directing the trajectories away from the maladaptive track. Researchers have reported that exogenous factors, such as parenting behaviors and peer relationships, perform as independent predictors of anxiety or mediators and moderators in the association between fearful temperament and anxiety (Affrunti et al., 2014; Kiel & Buss, 2009; Vasey & Dadds, 2001). Less research, however, have focused on the endogenous factors that underlie or alter the fearful temperament-anxiety link (White et al., 2011). Certain endogenous factors, such as attention, cognitive control, and motivational tendencies may perform as predictors of later anxiety or mediators and moderators linking fearful temperament and anxiety (Lonigan & Vasey, 2009; Pérez-Edgar et al., 2010). In this study, I examined the influences of multilevel factors and their complex interactions on the development of anxiety symptoms, including threat-related attention biases (AB), effortful control (EC), and frontal EEG asymmetry.

**Fearful Temperament, Attention Biases, and Anxiety**

AB appears to be involved in the onset and maintenance of anxiety for both children and adolescents (e.g., Bar-Haim et al., 2007; Hadwin et al., 2006). In Lau and Water’s (2017) recent annual review, they suggested AB as a proximal mechanism that mediated the effects of other distal (e.g., parenting behaviors, peer relationships) and predispositional (e.g. genetic, temperamental) risk factors on anxiety. Threat is usually defined as socially or non-socially frightening stimuli. Of note, the perception of threat is subjective and thus the threat source or
the saliency of a threatening item might be different to different people. In studies focused on fearful temperament, AB, and anxiety, the common types of stimuli include human angry faces, threat words (e.g., murder), and non-socially threatening images (e.g., threatening animals), with the most typical stimuli being angry faces. The strategy of using angry faces as threat stimuli may due to their emotional salience, as well as for the purpose of replication across research studies. A variety of tasks have been used to measure AB, such as the dot-probe task and the spatial cueing task. During AB tasks, threatening stimuli and neutral stimuli are presented and participants are assessed on whether they are faster in identifying and processing targets (e.g., the direction of arrows) associated with threatening stimuli or neutral stimuli.

It is important to note that AB measured with different stimuli presentation durations in tasks may have different underlying neural mechanisms. To be specific, short durations (e.g., 500 ms or less) typically indicate initial automatic AB. If we regard cognitive processing as a continuum that extends from automatic to regulatory, initial AB falls closer toward the automatic direction and is tied to the orienting attention system, which is a stimulus-driven system that prioritizes perceptual information for further processing (Morales et al., 2016). Orienting functions involve the superior parietal lobe, superior colliculus, temporal parietal junction, frontal eye fields, and pulvinar (Petersen & Posner, 2012). These structures are interconnected with the amygdala (Vuilleumier et al., 2004), which plays a significant role in threat detection and in mediating AB (Cisler & Koster, 2010; Monk et al., 2008). Longer durations (e.g., 1250 ms or more) usually indicate sustained AB that can be regulated or affected by both bottom-up and top-down systems, including the prefrontal cortex underlying EC (Fu & Pérez-Edgar, 2019; Lonigan et al., 2004).

Morales and colleagues (2016) recently proposed a hybrid model of the development of
AB, which suggests that there are early emerging individual differences in AB that are determined by intrinsic and extrinsic factors. For the majority of children, early-emerging AB supports adaptive patterns of vigilance in the face of threat and avoidance and helps individuals better adjust to the complex environments (LoBue et al., 2010). This normal pattern of AB toward threat represents an appropriate level of alertness that characterizes typical early development. It is important to note, however, that some children may show an atypical pattern of AB that manifests as habitual pre-tuning to threat or a lower threshold for detecting danger, unrealistically overestimating the threatening level of a stimulus, and exhibiting rigid and sustained attentional response to the detected threat (Cisler & Koster, 2010; Todd et al., 2012). Such an atypical type of AB can be caused by various individual risk factors and reinforce the development of psychopathology throughout childhood and adolescence.

As one of the most powerful individual risk factors for anxiety symptoms and anxiety disorders, fearful temperament is associated with the formation of an atypical pattern of AB. For example, in a study that examined AB in a group of children (4-7 years old) who tended to develop anxiety due to high fearful temperament, results indicated that children in the high-fear group are faster in detecting angry faces among happy faces compared with identifying happy faces among angry faces (LoBue & Pérez-Edgar, 2014). Similarly, results from another longitudinal study demonstrated that fearful temperament measured during toddlerhood and early childhood was associated with initial AB toward threat (i.e., 500 ms) during adolescence. Specifically, children who showed a higher level of fearful temperament tended to develop greater AB toward threat (Pérez-Edgar et al., 2010).

AB toward threat may cause an over processing of the negative features of a stimulus, underlying the vulnerability of anxiety (e.g., Telzer et al., 2008). For example, children (8-12
years old) with diagnoses of severe anxiety showed AB toward angry faces relative to neutral faces; a similar AB was not exhibited by children with less anxiety or children with no anxiety (Waters et al., 2010). Similarly, clinically anxious children and adolescents (7-18 years old) demonstrated a greater AB toward angry faces compared with non-anxious children (Roy et al., 2008). A study focusing on non-clinical children and adolescents found that AB toward threat was positively associated with self-reports of trait anxiety (Telzer et al., 2008). In another study investigating the duration of threat exposure, results indicated that a community sample of children (9-12 years old) who showed AB toward angry faces at exposure durations of both 500 ms and 1250 ms had higher levels of anxiety (Waters et al., 2010). A meta-analysis study indicated that children with anxiety showed a greater AB to threat-related stimuli relative to neutral stimuli (effect size of 0.54), compared with control children (effect size of 0.15; Dudeney et al., 2015).

Evidence supporting that AB toward threat may be causally implicated in the development of anxiety comes from intervention studies. Attention bias modification (ABM) was developed to improve the current treatment of anxiety. In ABM, the visual probe task is modified so that probes requiring a response appear more frequently at the positions previously occupied by neutral versus threat stimuli, thus facilitating a consistent AB away from threat over hundreds of trials for individuals whose tendency is to have an AB toward threat (Bar-Haim, 2010). ABM has been reported as a potentially promising treatment for anxiety (e.g., Chang et al., 2018). For example, in one report children with an on-going anxiety disorder showed reduced the symptoms of anxiety after ABM, compared with children in the control conditions (Eldar et al., 2012). Findings have been replicated with adolescents; specifically the ABM group experienced a significantly greater decrease in anxiety symptoms than participants in the control
group (Riemann et al., 2013). In addition, ABM was reported to reduce children’s state anxiety in response to a stressor task (Bar-Haim et al., 2011) and to also change neural activity. For example, in a group of 9- to 12-year-old children with fearful temperament, ABM significantly decreased amygdala and insula activation and increased activation in the ventrolateral prefrontal cortex compared with the control group (Liu et al., 2018).

**Fearful Temperament, Attention biases, Effortful Control, and Anxiety**

EC refers to the voluntary processes associated with modulating reactive or dominant responses, planning, and detecting an error (Rothbart & Rueda, 2005). The development of EC relies on the maturation of the executive attention system including the anterior cingulate cortex, anterior insula, basal ganglia, and the dorsolateral prefrontal cortex (Rothbart et al., 2007). EC shows the greatest improvement across toddlerhood and childhood and then becomes stable and reaches adult-level pattern during adolescence (Gerardi-Caulton, 2000; Luna et al., 2004; Simonds et al., 2007). EC contains several components, including attentional control (AC), inhibitory control (IC), and activation control (ACT; Rothbart et al., 2001), with the first two having been particularly associated with fearful temperament and anxiety. AC refers to the flexible control of attention (i.e., focusing and shifting) as needed. IC is the suppression of a dominant response to instead perform a subdominant one. ACT indicates the ability to initiate behaviors despite one’s affective inclination to avoid it (Rothbart et al., 2001).

The role of EC in the vulnerability of psychological disorders has been well recognized (e.g., Calkins & Fox, 2002; Muris & Ollendick, 2005). Children with high EC are better able to control their behaviors, attention, and emotions, therefore being less prone to psychopathology (Eisenberg et al., 2009). EC is often studied as a moderator in the association between reactive aspects of temperament (e.g., shyness, fear) and socio-emotional problems and it is the
combination of high negative reactive temperament and low EC that increases the risk of psychopathology (Muris, 2006; Oldehinkel et al., 2007; Verstraeten et al., 2009). Interestingly, more recent studies have revealed that different components of EC seem to have distinct effects on the continuity of fearful temperament and the relation between fearful temperament and anxiety. For example, in a study that examined the associations between different components of EC and fearful temperament trajectories across childhood, results indicated that children with higher attention shifting (a component of AC) had a lower initial level of fearful temperament and a slower decrease in it across childhood. Although their shyness decreased more slowly, it was still lower than the shyness of children with lower attention shifting. Children with higher IC showed a higher initial level of fearful temperament and a faster decline in it. Although their shyness decreased faster, it remained higher than the shyness of children with lower IC. ACT predicted a lower initial level of fearful temperament but was not related to the slope of it. (Eggum-Wilkens et al., 2016). In addition, high levels of AC buffered the risk for anxiety symptoms in toddlers with high levels of fearful temperament, whereas high levels of IC increased this risk for anxiety symptoms (White et al., 2011). Therefore, AC, IC, and ACT may differently modify the association between fearful temperament and anxiety across early childhood. IC particularly appears to increase the risk of anxiety for children with high level fearful temperament by leading to a rigid over-controlled system. AC lowers the risks by facilitating the flexible control of attention (White et al., 2011; but see Crockenberg & Leerkes, 2006; Liu et al., 2018). ACT contributes to the resilient process by forcing children to approach threats and thus habituate to threats although not motivated (Eggum-Wikens et al., 2016). In light of these findings, the three components of EC need to be treated separately in any discussion of how they moderate the association between fearful temperament and anxiety through AB.
The Role of Attentional Control

AC contributes to the resilient process by facilitating the disengagement of attention from threat, thus interrupting the non-adaptive sustained AB toward threat and lowering the risk of having anxiety (Henderson & Wilson, 2017; Lonigan et al., 2004). For example, in a study of children (9 to 18 years old) selected from a large screening sample for having high or low negative affectivity (NA) and EC, results indicated that EC moderated the association between NA and AB. Specifically, children showed greater AB toward threat when they had high NA and low EC. For those with high EC, however, NA was not significantly associated with AB (Lonigan & Vasey, 2009). It is worth noting that EC in this study was mainly AC measured with the self-report scales that emphasize the flexible control of attention (e.g., Effortful Control Scale). Moreover, AB was measured via the dot-probe task with a 1250 ms stimuli exposure duration, which is thought to reflect the sustained AB that can be affected by EC (Lonigan et al., 2004).

Similarly, in another community sample of children (9 to 14 years old), those with a high level of self-reported temperamental fear showed greater AB toward treat. The association between fear and AB was significant, however, only when children had low AC, but not when they had medium or high AC (Susa et al., 2014). Interestingly, AB in this study was tested with stimuli presented for only 500 ms, which is usually regarded as a duration that reflects more automatic AB (Vervoort et al., 2011). Lonigan and colleagues (2014), however, argued that to test the moderating effect of EC between negative temperament and AB, stimuli should be presented long enough to permit the intentional control of attention (i.e., 1250-1500 ms). In this study, I sought to clarify these inconsistent findings by examining the moderating effect of AC on AB measured with both short (e.g., 500 ms) and long duration (i.e., 1250 ms).
Although a growing literature has demonstrated the role of AC in the association between fearful temperament and AB, the existing body of work is limited in two important ways. First, the majority of research has utilized a cross-sectional design, which limits the potential directional interpretations about the predictive effect of fearful temperament and AC on AB. Second, a large proportion of studies heavily relied on self-reports and maternal reports (Lonigan & Vasey, 2009; Pavlou et al., 2016; Susa et al., 2014). Exclusively depending on questionnaires can be problematic when other variables in the study (e.g., temperament) are measured via questionnaires as well because it may overestimate the correlations among the variables of interest due to common method biases. It is important for future research to complement questionnaires with other measurements, such as behavioral tasks (e.g., Attention Network Test).

The Role of Inhibitory Control and Activation Control

Studies examining the functions of IC and ACT in the context of fearful temperament, AB, and anxiety are limited. The lack of empirical work maybe because AC is thought to be more relevant to AB in the visual domain compared with IC and ACT, which are generally considered a characteristic related to the suppression or initiation of behaviors or actions (Bari & Robbins, 2013).

To examine the underlying mechanisms by which EC affects the association between fearful temperament and anxiety, Henderson and Wilson (2017) recently proposed a model focused on the different roles of AC and IC. Specifically, Henderson and Wilson suggest that initial, automatic AB toward threat is prolonged by high IC. Because the combination of IC and fearful temperament creates an inflexible over-controlled system, fearful children with high IC are more likely to get stuck on threatening stimuli, and therefore are at higher risk of anxiety. It is also suggested that interventions that aim to improve children’s ACT can facilitate children to
engage in peer interactions from a young age, therefore reduce the risk of social wariness and anxiety (Henderson & Wilson, 2017). There is empirical research, however, reporting that IC and ACT were uniquely associated with depression but not anxiety in children and adults (Moriya & Tanno, 2008; Verstraeten et al., 2011). Further research should investigate the role of IC and ACT in the expression of anxiety in children and adolescents. To my best knowledge, no study has examined the roles of IC and ACT in the association among fearful temperament, AB and anxiety symptoms from middle childhood to adolescence. My study aimed to reveal the nature of the associations among specific aspects of EC and anxiety symptoms.

**Fearful temperament, Attention Biases, Frontal EEG Asymmetry, and Anxiety**

Evidence from psychophysiological studies suggest that frontal EEG asymmetry may act as an important biomarker that correlates to individuals’ psychopathology (e.g., Peltola et al., 2014). Frontal EEG asymmetry refers to the asymmetrical brain electrical activity in the anterior regions of the two hemispheres, which is typically indicated by the mathematical difference in EEG alpha power between the hemispheres (Reznik & Allen, 2017). EEG power reflects the excitability of clusters of neurons (Bell & Cuevas, 2012), with the alpha rhythm being the dominant rhythm observed in awake individuals of all ages (Marshall et al., 2002). The specific frequency band for the alpha rhythm changes with development (see Cuevas & Bell, in press, for a review).

The pattern of frontal EEG asymmetry has been widely related to dispositional emotion (Tomarken et al., 1992), approach-withdrawal motivation (Fox, 1994), and psychopathology (Coan & Allen, 2004). According to the motivational direction model, left frontal EEG asymmetry reflects approach motivation associated with both positive (e.g., enthusiasm) and negative (e.g., anger) emotional valence (Harmon-Jones & Gable, 2018), whereas right frontal
EEG asymmetry reflects avoidance or withdrawal motivation typically associated with negative emotion (e.g., sadness; Sutton & Davidson, 1997). In line with the model, empirical evidence has shown that left frontal EEG asymmetry is associated with externalizing problems (e.g., aggression, rule breaking) and right frontal EEG asymmetry is associated with internalizing problems (e.g., anxiety, depression, withdrawal) for children and infants (e.g., Gatzke-Kopp et al., 2014; Smith & Bell, 2010).

The role of frontal EEG asymmetry has been demonstrated as a moderator between negative temperament, emotional arousal, and psychopathology (see Reznik & Allen, 2018, for a review). For example, negative emotionality at 9 months predicts social wariness at 4 years only for infants with right frontal EEG asymmetry (Henderson et al., 2001). Similarly, fearful preschoolers who showed greater right frontal EEG asymmetry tended to exhibit more internalizing problems compared with inhibited preschoolers who showed left frontal EEG asymmetry (Fox et al., 1996). Moreover, a cross-sectional study reported that frontal EEG asymmetry moderates the association between electrodermal reactivity to a sad film and psychopathology in kindergarten children (M = 6.03 years). Specifically, increased arousal in response to the sad clip was associated with greater internalizing problems among children with right frontal EEG asymmetry (Gatzke-Kopp et al., 2014). These findings are consistent with the motivational direction model showing that the association between fearful temperament and internalizing problems is stronger when children have greater right frontal EEG asymmetry.

There are reciprocal metabolic connections between the left prefrontal cortex and the amygdala. Human brain imaging and animal lesion research suggests that these metabolic processes are the mechanism linking frontal EEG asymmetry with emotion-related behaviors (Davidson, 2001). In addition, asymmetrical alpha activity has been related to attentional
processing in the frontal-parietal network (e.g. Sauseng et al., 2011). Therefore, the possibility that frontal EEG asymmetry affects emotional processing and disorders through its influences on AB warrants further investigation. Frontal EEG asymmetry may interact with fearful temperament in the prediction of AB underlying adolescent anxiety.

Of note, previous EEG asymmetry studies mainly focused on the frontal EEG asymmetry that is measured at baseline. According to the capability model, however, frontal EEG asymmetry reflects the interactions between the specific emotional demands of a specific situation and the emotion regulation ability people bring to that situation, thus individual differences in EEG asymmetries may be most pronounced in the emotionally challenging tasks (Coan, Allen, & Mcnight, 2006). Although it has been reported that right frontal EEG asymmetry measured at baseline predicts greater AB toward threat (Miskovic & Schmidt, 2010), there are studies failing to find so. For instance, frontal EEG asymmetry at baseline does not predict AB to angry faces. Nevertheless, increases in right frontal EEG asymmetry from baseline to a stressful speech condition were associated with vigilance to angry faces and avoidance of happy faces (Pérez-Edgar et al., 2013). Considering this, I predicted that asymmetrical frontal activation from baseline to task (FA) moderated the association between fearful temperament and AB as well as anxiety. Given that AB assessed with both short and long stimulus presentation durations have been affected by FA (Grimshaw et al., 2014; Pérez-Edgar et al., 2013), I would test the moderation effect of FA on both initial and sustained AB.

The Current Study

Children with fearful temperament are at increased risk of anxiety during adolescence (Degnan et al., 2010). The mechanisms linking early temperament and anxiety symptoms, however, are complex and have not been fully investigated. My study aimed to examine the
multiple individual characteristics that explain individual differences in the development of anxiety symptoms, with a specific focus on attention, cognitive control, and motivation system.

Fearful children are more vigilant to threat and have more difficulties in disengaging from threat once being captured (LoBue & Pérez-Edgar, 2014). This abnormal AB may partly explain the onset of anxiety symptoms. Having a specific pattern of EC and FA, may discourage the development of anxiety by overcoming the non-adaptive AB (Lau & Water, 2017). EC contains three aspects, which may play different roles in the association among fearful temperament, AB, and anxiety (Henderson & Wilson, 2017). Previous research, however, has dominantly focused on the effect of AC, leaving the other two aspects of EC less examined. Further efforts are warranted in fully investigating the roles of different aspects of EC in the development of AB and anxiety. It is well established that FA is a biomarker of emotional reactivity and psychopathology (Coan & Allen, 2004). Limited research, however, has examined its association with AB. Among the few studies that did so, all of them studied young adults and utilized a cross-sectional design (e.g., Grimshaw et al., 2014; Pérez-Edgar et al., 2013). My study represents the first step in examining the moderating effect of FA on the association between fearful temperament and AB during middle childhood to adolescence using a longitudinal design. Given the findings from prior literature, I made the following hypotheses:

1. Fearful temperament at 9 years will indirectly predict adolescent anxiety through adolescent AB (Figure 1).

2. AC at 9 years will moderate the association between fearful temperament at 9 years and adolescent anxiety. Specifically, fear will predict anxiety symptoms when children have low AC. AC will moderate the association between fear at 9 years and sustained AB but not automatic AB during adolescence (Figure 2).
3. IC at age 9 years of age will moderate the association between fearful temperament and adolescent anxiety symptoms. Specifically, fear will predict anxiety symptoms when children have high IC. The interactive effect of fearful temperament and IC on AB will remain exploratory given the limited findings in previous research (Figure 3).

4. ACT at 9 years of age will moderate the association between fearful temperament and adolescent anxiety symptoms. Specifically, fear will predict anxiety symptoms when children have low ACT. The interactive effect of fearful temperament and ACT on AB will remain exploratory given the limited findings in previous research (Figure 4).

5. FA at 9 years of age will moderate the association between fearful temperament at 9 years and adolescent anxiety. Specifically, fear will predict anxiety symptoms when children show greater right frontal activation from baseline to task. FA will moderate the association between fear at 9 years and AB during adolescence (Figure 5).
Method

Participants

My sample included 2 cohorts of children from an ongoing longitudinal investigation of cognition and emotion development from infancy and across childhood and adolescence. These children visited our lab at 9 years of age. Of the 161 children (77 boys, 84 girls) participating at 9 years old, 78 returned for the final visit of the study during adolescence (i.e., 12-17 years of age). Data collection for the adolescent lab visits began in August 2019 and continued through mid-March 2020, when the University closed campus due to COVID-19 concerns. Because part of the ongoing longitudinal study focused on mother-child interactions, mother was the parent who always accompanied the child to the lab visits. Similarly, mother was the parent who completed all questionnaires associated with the study.

Among the 78 children (33 boys, 45 girls) on whom these analyses were conducted, 91% are White, 6.4% are Multi-racial/Other, 2.6% are Asian. Children received a $20 gift certificate and mothers received a $75 gift certificate as compensation for participation at age 9. Children received $50 cash and mothers received $50 cash as compensation for the adolescent visit.

Procedures

Children visited our lab at 9 years during the summer of 2015 and visited again in Fall 2019 and Spring 2020 to participate in the final adolescent visit of our longitudinal research. When arriving at the research lab each time, children and their parents were greeted, and procedures were described by the researchers. After getting the signed consent and assent from parents and children, researchers began to place the ECG disposable electrodes and EEG electrode cap on the children and administer various cognitive, socio-emotional, and academic achievement tests. Mothers sat in an adjoining room and completed questionnaires during the
appointments. Only the tasks and questionnaires used in my dissertation are described in this method section.

**Measures Collected at the 9-year Lab Visit**

*Fearful Temperament.* Early Adolescent Temperament Questionnaire-Revised (EATQ-R; Ellis & Rothbart, 2001) is an assessment of temperament and behavior in children and adolescents containing 62 items in 10 subscales in the parent-report version. Parents responded on a 5-point Likert scale ranging from 1=almost never true to 5=almost always true. In the current study, the fear subscale of the EATQ was used to assess fearful temperament (6 items, e.g., “Worries about getting into trouble.”) The Cronbach’s alpha of fear subscale is .64.

*Attentional Control.* Three measures were used to assess AC at age 9.

  **Attention Network Test** (ANT; Fan et al., 2002). The Attention Network Test is designed to measure the efficiency of three different attention networks: alerting, orienting, and executive attention. Children sat in front of a laptop computer and were asked to indicate the direction of the center arrow as quickly and accurately as possible. Trials varied in weather having cues (no cue; one cue; double cue; spatial cue) and if the direction of the center arrow is the same as the surrounded flankers (neutral; congruent; incongruent). The variable of interest in my study was executive attention, which was measured by subtracting the reaction time in the congruent condition from the incongruent condition.

  **Early Adolescent Temperament Questionnaire-Revised** (EATQ-R; Ellis & Rothbart, 2001). The attention subscale (6 items; e.g., “Is good at keeping track of several different things that are happening around her/him”) was used to measure attention control by parent report. The Cronbach’s alpha of the subscale is .79.
**Behavior Rating Inventory of Executive Function** (BRIEF; Gioia et al., 2000). The parent report of the BRIEF is an 86-item questionnaire that measures the executive functions in everyday situations of youth between 5 and 18 years of age. It is comprised of eight scales (e.g., initiate, emotional control, shift, inhibit). Parents rated on a 3-point Likert scale indicating whether each behavior occurs never, sometimes, or often. Higher scores indicate more problems in executive function. In the current study, the standardized T score of the shift scale (e.g., “Tries the same approach to a problem over and over even when it does not work”) was used to indicate AC (Cronbach’s alpha = .82).

**Inhibitory Control.** Three measures were used to assess IC at age 9.

**Number Stroop Task** (Ruffman et al., 2001). A computerized number Stroop task was administrated to test children’s inhibitory control. There were three sections in the number Stroop task. In the control section, children were presented with a string of letters on the screen, and they were asked to count the number of letters as quickly and accurately as possible. For example, if children were shown “AAA”, the correct answer was 3 given there are three letters in the string. In the conflict section, children counted numbers instead of letters with the same rule as the control section. For example, if children were shown “6666”, the correct answer was 4 given there are 4 numbers in the string. The conflict section required children to inhibit the dominant tendency to say the number they see, and instead reporting how many numbers on the screen. In the mixed section, children were presented with either strings of letters or numbers, and they were asked to count how many letters or numbers on the screen. The variable of interest was the reaction time in the conflict section.

**Early Adolescent Temperament Questionnaire-Revised** (EATQ-R; Ellis & Rothbart, 2001). The inhibitory control subscale (5 items; e.g., “Is more likely to do something s/he
shouldn’t do the more s/he tries to stop her/himself”) was used to measure attention control by parent report. The Cronbach’s alpha of the subscale is .69.

**Behavior Rating Inventory of Executive Function** (BRIEF; Gioia et al., 2000). The standardized T score of inhibit scale (e.g., “Acts wilder or sillier than others in groups”) of the BRIEF was used to assess the level of IC by parent report. The Cronbach’s alpha of the subscale is .89.

**Activation Control.** Two measures were used to assess IC at age 9.

**Early Adolescent Temperament Questionnaire-Revised** (EATQ-R; Ellis & Rothbart, 2001). The activation control subscale (5 items; e.g., “Has a hard time finishing things on time”) was used to measure attention control by parent report. The Cronbach’s alpha of the subscale is .84.

**Behavior Rating Inventory of Executive Function** (BRIEF; Gioia et al., 2000). The standardized T score of initiate scale (e.g., “Is not a self-starter”) of the BRIEF was used to assess the level of IC by parent report. The Cronbach’s alpha of the subscale is .81.

**Frontal EEG Asymmetry.** FA at 9 years of age was examined for my dissertation project. The baseline EEG was accomplished as the child watched a 3-minute video (opening scene from Lion King). The task EEG was recorded as the child engaged in a visual search task. The child was asked to find all the visual targets (i.e. stars) among other distractors within a specified time under the experimenter’s intense gaze. The task was originally designed to assess children’s executive function and was chosen for my dissertation study as it was a moderately stressful situation that might elicit a certain level of anxious feelings. EEG was recorded at age 9 from 26 left, right, and midline scalp sites, all referenced to Cz during the recordings. Electrode impedances were measured and accepted if they were below 10 KΩ. The electrical activity from
each lead was amplified and bandpassed from .1 to 100 Hz and the signal digitized on-line at 512 Hz. EEG data were examined and analyzed using EEG Analysis System software developed by James Long Company (Caroga Lake, NY). Data were re-referenced the data via software to an average reference configuration, which was then artifact scored for eye movements and gross motor movements so that only artifact-free data were used. The data were then analyzed with a discrete Fourier transform (DFT) using a Hanning window of 1 second width and 50% overlap. EEG power was expressed as mean square microvolts and the data were transformed using the natural log (ln) to normalize the distribution.

Power was computed at the 8-10 Hz alpha frequency band. According to research that examined the power distribution in preschool children (Marshall et al., 2002), alpha corresponds to 6-9 Hz in 4-year-old children. The alpha band is typically shifted by 1-2 Hz from preschool children to school-age children based on their age-dependent peak frequencies (Niedermeyer, 1999). Therefore, alpha likely corresponds to 8-10 Hz in 9-year-old children. This frequency band has indeed been used by Forbes and colleagues (2006) and Vuga and colleagues (2008) with children in the middle childhood age range.

Baseline and task frontal EEG asymmetry were calculated by subtracting the ln power at left hemisphere (F3) from ln power at right hemisphere (F4; Fox, 1994). Baseline to task frontal activation was calculated by subtracting the frontal asymmetry scores at baseline from the frontal asymmetry scores during task. Left FA was indicated by positive EEG asymmetry values, which meant greater left activation from baseline to task. Right FA was indicated by negative EEG asymmetry values, which meant greater right activation from baseline to task. This is because cortical activity is inversely related to alpha power (Reznik & Allen, 2017).

**Measures Collected at the Adolescent Lab Visit**
**Attention Biases.** AB was assessed behaviorally.

**Dot-probe task** (Pérez-Edgar et al., 2010; Suway et al., 2013). The face stimuli were photographs of 20 different actors (10 male; 10 female) taken from the NimStim stimulus set (Tottenham et al., 2009). Stimuli were presented on a CRT monitor viewed at a distance of 100 cm and presentation was controlled by the STIM stimulus presentation system from the James Long Company (Caroga Lake, NY). Each trial began with a 500 ms fixation cross presented at the center of the screen, followed by a horizontal face pair displayed for either 500 ms or 1250 ms. The face photographs were presented side by side equidistant from the fixation cross (subtending 0.8 x 0.8 degrees). Each face image subtended 8.8 x 7.6 degrees of visual angle and was centered 6.6 degrees to the left or right of the fixation cross. Immediately following the offset of the faces, a target arrow probe, pointing up or down, was presented for 500 ms, centered in the location of one of the previously presented faces. The arrow probe subtended 1.0 x 0.8 degrees of visual angle. Participants were asked to indicate as quickly and accurately as possible whether the arrow points up or down using a two-button box. The arrow presentation was replaced by a blank screen in which the participants have up to 750 ms to respond to the target orientation before the next trial began.

There were two types of face pairs: angry-neutral (256 trials) and neutral-neutral (128 trials). Trials were considered as congruent if the arrow appears in the same location as the angry face (128 trials) and incongruent if appearing in the location of the neutral face (128 trials). Participants received 10 practice trials. Trials were organized into blocks based on the face presentation durations. There was a total of 384 test trials divided into four blocks (i.e. two blocks of 500 ms and two blocks of 1250 ms). Within each block, face sex, angry face location
(right/left), probe direction (up/down), and probe location (right/left) were counterbalanced. The trial order within a block was randomized. A short break was delivered between blocks.

Dot-probe trials with incorrect response and reaction times (RTs) less than 200 ms or more than 1250 ms were excluded from further analyses to avoid random responses or responses that may be influenced by distractions. In addition, RTs were averaged across block and RTs above and below three standard deviations of the mean RT were excluded from the mean RT calculation for each participant. Bias scores were calculated by subtracting mean RTs for congruent from mean RTs for incongruent trials, such that positive scores indicated AB towards threat and negative scores reflected AB away from threat.

**Anxiety.** Adolescent anxiety symptoms were assessed via parent-report.

**The Revised Children’s Anxiety and Depression Scale** (RCADS; Chorpita et al., 2000). RCADS is a 47-item questionnaire that measures five anxiety subtypes (i.e. separation anxiety disorder, social phobia, generalized anxiety disorder, panic disorder, obsessive compulsive disorder) and depression symptoms. Parents report the frequency of their children’s symptoms on a 4-pointed Likert Scale (0 = never, 1 = sometimes, 2 = often, 3 = always). Previous studies showed good test-retest reliability, internal consistency, concurrent validity, and discriminant validity of the questionnaires in both clinical and non-clinical youth samples (Chorpita et al., 2000; Chorpita et al., 2005). The variable of interest in the current study was the total anxiety scores. The Cronbach’s alpha of the total anxiety scale is .89.

**Data Analysis Strategy**

Confirmatory factor analysis was conducted to test the measures of AC and IC. First, the variables were standardized and multiplied by -1 (if necessary) to make sure all the variables are on the same scale with the same direction. For the AC model, data were analyzed with all three
observable variables (ANT, EATQ-attention, and BRIEF-shift) loading on the latent AC factor. For the IC model, data were analyzed with all three observable variables (Stroop, EATQ-IC and BRIEF-inhibit) loading on the latent IC factor.

**Hypotheses 1.** Path models were examined to test the indirect effect of fearful temperament on anxiety through automatic and sustained AB via Mplus 7.4 (Muthén & Muthén 2015). Full information maximum likelihood (FIML) was used to handle missing values. An MLR estimator was used to account for possible non-normal distribution of the study variables. I refer to the codes developed by Stride and colleagues (2015) based on the instructions given by Hayes (2017; model 4).

**Hypotheses 2 to 5.** Path models and structural equation models were examined via Mplus 7.4 (Muthén & Muthén 2015). Full information maximum likelihood (FIML) was used to handle missing values. An MLR estimator was used to account for possible non-normal distribution of the study variables. I refer to the codes developed by Stride and colleagues (2015) based on the instructions given by Hayes (2017; model 8). Specifically, 1) I tested the interactive effect of fearful temperament and EC or FA on AB; 2) I tested the interactive effect of fearful temperament and EC or FA on anxiety with AB being controlled as a covariate; 3) I tested the potential moderated mediation associations among fearful temperament, AB, EC, FA, and anxiety symptoms, although the statistical power might not be sufficient due to the moderate sample size in this study. Considering adolescent girls are at higher risk of psychopathology compared with adolescent boys (Van Oort et al., 2009), sex was entered as control variables in predicting adolescent anxiety symptoms.

Model fit was assessed using the chi-square goodness-of-fit statistics, comparative fix index (CFI), root mean square error of approximation (RMSEA), and standardized root mean
square residual (SRMR). A non-significant chi-square statistic value, a CFI value greater than .95, an RMSEA value less than .06, and a SRMR value less than .08 indicated good model fit (Hu & Bentler, 1999). If the interactive terms were significant in predicting AB or anxiety, I used one SD plus and minus the mean of the moderator to plot variables and to test the statistical significance of each simple slope (Aiken et al., 1991).
Results

Preliminary Analysis

The factor loadings of ANT, EATQ-attention, and BRIEF-shift on AC were not significant (see Table 1). Therefore, only ANT and BRIEF-shift were used to indicate AC in this study ($r = .32, p = .01$; the correlation coefficient between ANT and EATQ-attention was not significant). The standardized scores of ANT and BRIEF-shift were averaged to create a composite score indicating AC. The factor loadings of Stroop, EATQ-IC, and BRIEF-inhibit on IC were significant and in the expected direction (see Table 1). Therefore, all three measures were used to indicate IC as part of the structural equation model. To measure ACT, the scores of BRIEF-initiate and EATQ-activation control were standardized and averaged to compute a composite score of ACT ($r = .67, p < .001$).

Descriptive statistics and correlations among the variables of interest are presented in Table 2 and Table 3. Fearful temperament at age 9 was significantly correlated with adolescent anxiety symptoms. The association between AB and fear as well as anxiety, however, were not significant. Adolescent girls had higher level of anxiety compared with boys ($t = 3.57, p < .001$).

Fearful temperament, AB, and anxiety

Automatic AB (500 ms)

The path model fitted the data well, $\chi^2 = .71, p = .70$, CFI = 1.00, RMSEA = .00, SRMR = .03. Fear at 9 years significantly predicted adolescent anxiety ($b = 4.49, p = .001$) controlling for sex ($b = -6.65, p < .001$). However, fear did not predict automatic AB during adolescence ($b = -3.68, p = .23$). AB was not associated with anxiety ($b = .03, p = .54$). Fear did not indirectly predict anxiety through automatic AB ($b = -.11, p = .61$, 95% CI, $-.47$ to $.25$).

Sustained AB (1250 ms)
The path model fitted the data well, $\chi^2 = .74$, $p = .69$, CFI = 1.00, RMSEA = .00, SRMR = .03. Fear at 9 years significantly predicted adolescent anxiety ($b = 4.52$, $p = .001$) controlling for sex ($b = -6.92$, $p < .001$). However, fear did not predict sustained AB during adolescence ($b = -2.57$, $p = .34$). AB was not associated with anxiety ($b = .06$, $p = .26$). Fear did not indirectly predict anxiety through sustained AB ($b = -.14$, $p = .43$, 95% CI, $-.44$ to .16).

Fearful temperament, AB, AC, and anxiety

*Automatic AB (500 ms)*

The path model fitted the data well, $\chi^2 = 1.91$, $p = .75$, CFI = 1.00, RMSEA = .00, SRMR = .04. Fear at 9 years significantly predicted adolescent anxiety ($b = 3.14$, $p = .01$). The main effect of fear was qualified by a significant interaction between fear and AC ($b = -3.54$, $p = .01$; Table 4). Specifically, fear at age 9 predicted adolescent anxiety only when children had low AC ($b = 5.97$, $p < .001$) but not high AC ($b = .31$, $p = .87$) at 9 years. The main effect of fear or the interactive effect between fear and AC on automatic AB were not significant. Automatic AB was not associated with anxiety ($b = .07$, $p = .17$). Given the focus of my dissertation is on AB, I chose to graph only the significant moderation effects that involved AB. Specifically, all the simple slopes figures in the dissertation are for sustained AB and for anxiety symptoms with sustained AB being controlled.

*Sustained AB (1250 ms)*

The path model fitted the data well, $\chi^2 = 2.48$, $p = .65$, CFI = 1.00, RMSEA = .00, SRMR = .04. AC at 9 years moderated the association between fear at 9 years and sustained AB during adolescence ($b = -6.37$, $p = .02$; Table 5). Specifically, fear predicted AB away from threat when children showed high AC ($b = -8.32$, $p = .02$). The association between fear and AB was not significant when children showed low AC ($b = 1.87$, $p = .61$; see Figure 6). In addition, fear at 9

25
year significantly predicted adolescent anxiety \((b = 3.21, p = .01)\). The main effect of fear was qualified by a significant interaction between fear and AC \((b = -3.23, p = .02)\). Specifically, fear at age 9 predicted adolescent anxiety only when children had low AC \((b = 5.80, p < .001)\) but not high AC \((b = .63, p = .73)\) at 9 years (see Figure 7). Sustained AB was not associated with anxiety \((b = .03, p = .51)\).

**Fearful temperament, AB, IC, and anxiety**

*Automatic AB (500 ms)*

Fit indices were not available for structural equation model when type was set as random in Mplus, thus was not provided in the present study. Fear at 9 year significantly predicted adolescent anxiety \((b = 5.09, p < .001)\). The main effect of fear was qualified by a significant interaction between fear and AC \((b = -4.01, p < .001; \text{Table 6})\). Specifically, fear at age 9 predicted adolescent anxiety only when children had low IC \((b = 9.09, p < .001)\) but not high IC \((b = 1.08, p = .59)\) at 9 years. The main effect of fear or the interactive effect between fear and IC on automatic AB were not significant. Automatic AB was not associated with anxiety \((b = .04, p = .45)\).

*Sustained AB (1250 ms)*

Fit indices were not available for structural equation model when type was set as random in Mplus, thus was not provided in the present study. IC at 9 years moderated the association between fear at 9 years and sustained AB during adolescence \((b = -5.19, p = .04; \text{Table 7})\). Specifically, fear predicted AB away from threat when children showed high IC \((b = -6.85, p = .04)\). The association between fear and AB was not significant when children showed low IC \((b = 3.53, p = .41; \text{see Figure 8})\). In addition, fear at 9 year significantly predicted adolescent anxiety \((b = 4.96, p < .001)\). The main effect of fear was qualified by a significant interaction
between fear and IC (b = -3.90, p = .01). Specifically, fear at age 9 predicted adolescent anxiety only when children had low IC (b = 8.86, p < .001) but not high IC (b = 1.05, p = .61) at 9 years (see Figure 9). Sustained AB was not associated with anxiety (b = .03, p = .56).

**Fearful temperament, AB, ACT, and anxiety**

*Automatic AB (500 ms)*

The path model fitted the data well, $\chi^2 = .86$, $p = .35$, CFI = 1.00, RMSEA = .00, SRMR = .02. Fear at 9 years significantly predicted adolescent anxiety (b = 4.73, $p < .001$). The main effect of fear was qualified by a significant interaction between fear and ACT (b = -2.51, $p = .04$; Table 8). Specifically, fear at age 9 predicted adolescent anxiety only when children had low ACT (b = 6.99, $p < .001$) but not high ACT (b = 2.48, $p = .22$) at 9 years. The main effect of fear or the interactive effect between fear and ACT on automatic AB were not significant. Automatic AB was not associated with anxiety (b = .03, $p = .49$).

*Sustained AB (1250 ms)*

The path model fitted the data well, $\chi^2 = 1.28$, $p = .26$, CFI = .99, RMSEA = .06, SRMR = .03. Fear at 9 years significantly predicted adolescent anxiety (b = 4.80, $p < .001$). The main effect of fear was qualified by a significant interaction between fear and ACT (b = -2.39, $p = .04$; Table 9). Specifically, fear at age 9 predicted adolescent anxiety only when children had low ACT (b = 6.95, $p < .001$) but not high ACT (b = 2.64, $p = .18$) at 9 years (see Figure 10). The main effect of fear or the interactive effect between fear and ACT on sustained AB were not significant. Sustained AB was not associated with anxiety (b = .05, $p = .33$).

**Fearful temperament, AB, FA, and anxiety**

*Automatic AB (500 ms)*
The path model fitted the data well, $\chi^2 = 2.38, p = .30$, CFI = .97, RMSEA = .05, SRMR = .03. Fear at 9 year significantly predicted adolescent anxiety ($b = 4.07, p < .001$). The main effect of fear was qualified by a significant interaction between fear and FA ($b = -2.80, p = .02$; Table 10). Specifically, fear at age 9 predicted adolescent anxiety only when children had greater right activation from baseline to task ($b = 6.87, p < .001$) but not greater left activation ($b = 1.27, p = .49$) at 9 years. The main effect of fear or the interactive effect between fear and FA on automatic AB were not significant. Automatic AB was not associated with anxiety ($b = .04, p = .39$).

**Sustained AB (1250 ms)**

The path model fitted the data well, $\chi^2 = 1.55, p = .50$, CFI = 1.00, RMSEA = .00, SRMR = .03. FA at 9 years moderated the association between fear at 9 years and sustained AB during adolescence ($b = -4.88, p = .05$; Table 11). Specifically, fear predicted AB away from threat when children showed greater left activation from baseline to task ($b = -9.03, p = .04$). The association between fear and AB was not significant when children showed greater right activation ($b = 0.74, p = .81$; see Figure 11). In addition, fear at 9 year significantly predicted adolescent anxiety ($b = 4.02, p < .001$). The main effect of fear was qualified by a significant interaction between fear and FA ($b = -2.63, p = .03$). Specifically, fear at age 9 predicted adolescent anxiety only when children showed greater right activation from baseline to task ($b = 6.65, p < .001$) but not greater left activation ($b = 1.40, p = .45$) at 9 years (see Figure 12). Sustained AB was not associated with anxiety ($b = .02, p = .74$).

**Summary**

1. Fearful temperament at 9 years indirectly predicted adolescent anxiety through adolescent AB (Figure 1).
Hypothesis 1 was not supported by the results. Fearful temperament did not indirectly predict anxiety through neither automatic AB nor sustained AB.

2. AC at 9 years moderated the association between fearful temperament at 9 years and adolescent anxiety. Specifically, fear predicted anxiety symptoms when children had low AC. AC moderated the association between fear at 9 years and sustained AB but not automatic AB during adolescence (Figure 2).

Hypothesis 2 was supported by the results. Fear at 9 years predicted adolescent anxiety symptoms when children had low AC at 9 years. Fear at 9 years predicted sustained AB away from threat during adolescence when children had high AC at 9 years.

3. IC at age 9 years of age moderated the association between fearful temperament and adolescent anxiety symptoms. Specifically, fear predicted anxiety symptoms when children had high IC. The interactive effect of fearful temperament and IC on AB remained exploratory given the limited findings in previous research (Figure 3).

Hypothesis 3 was not supported by the results. Fear at 9 years predicted adolescent anxiety symptoms when children had low IC at 9 years. Fear at 9 years predicted sustained AB away from threat during adolescence when children had high IC at 9 years.

4. ACT at 9 years of age moderated the association between fearful temperament and adolescent anxiety symptoms. Specifically, fear predicted anxiety symptoms when children had low ACT. The interactive effect of fearful temperament and ACT on AB remained exploratory given the limited findings in previous research (Figure 4).

Hypothesis 4 was supported by the results. Fear at 9 years predicted adolescent anxiety symptoms when children had low ACT at 9 years. ACT, however, did not moderate the association between fear and AB.
5. FA at 9 years of age moderated the association between fearful temperament at 9 years and adolescent anxiety. Specifically, fear predicted anxiety symptoms when children showed greater right frontal activation from baseline to task. FA moderated the association between fear at 9 years and AB during adolescence (Figure 5).

Hypothesis 5 was partly supported by the results. Fear at 9 years predicted adolescent anxiety symptoms when children had greater right activation from baseline to task at 9 years. Fear at 9 years predicted sustained but not automatic AB away from threat during adolescence when children had greater left activation from baseline to task at 9 years.
Discussion

In this study, I examined various factors that underlie the association between fearful temperament at age 9 and adolescent anxiety symptoms including AB, different components of EC (i.e., AC, IC, and ACT), and FA. I found that fearful temperament at age 9 significantly predicted adolescent anxiety symptoms controlling for sex. This association, however, was moderated by children’s EC and FA at age 9. Specifically, fear at 9-year-old positively predicted adolescent anxiety only when children had low AC, low IC, low ACT, and exhibited greater right activation from baseline to task. Fear at 9 years did not predict adolescent anxiety for children who had high AC, high IC, high ACT, and exhibited greater left activation from baseline to task. Inconsistent with my hypothesis, the associations between AB and fearful temperament as well as anxiety were not significant. Fear at 9 years did not indirectly predict adolescent anxiety through AB. However, I found that the association between fear at 9 years and sustained AB but not automatic AB during adolescence was moderated by children’s AC, IC, and FA at age 9. Specifically, fear predicted AB away from threat when children had high AC, high IC, and showed greater left activation from baseline to task. Sex predicted anxiety symptoms indicating girls are more vulnerable to anxiety symptoms than boys. The findings will be discussed in terms of the role of AB in the onset of anxiety and how different components of EC and FA contribute to the resilience process by moderating the association between fearful temperament and AB as well as anxiety symptoms.

Fearful temperament, AB, and anxiety

In this study, neither fearful temperament nor anxiety symptoms were correlated with AB. This finding was inconsistent with previous literature indicating that fearful temperament affects the way children process threat-related information, which may serve as a risk factor for
the development of anxiety symptoms (e.g., Bar-Haim et al., 2007; Hadwin et al., 2006; Lau & Water, 2007; Pérez-Edgar et al., 2010). The nonsignificant association between AB and fearful temperament as well as anxiety can be explained by several possible reasons. To begin, participants in this study were a community sample of children who were not screened for having high fearful temperament as what did by a number of previous studies (e.g, LoBue & Pérez-Edgar, 2014; Pérez-Edgar et al., 2010). Therefore, the overall level of fearful temperament in the current sample was low to moderate and might not be salient enough to alter the way children process threatening stimuli or to cause an extreme abnormal pattern of threat processing that underlies anxiety symptoms. Second, fearful temperament was measured with the fear subscale of the EATQ (Ellis & Rothbart, 2001). This is different from some previous research that applied behavioral observation measures rather than maternal report to assess fearful temperament (e.g., White et al., 2017).

Third, the inconsistency between the current finding and previous literature partly may be due to the limitation of using reaction time to indicate AB. Although AB has been widely used, the psychometric properties of the task are questionable. For example, evidence from previous studies indicating low split-half and test-retest reliability scores of reaction time tasks used to assess AB (Brown et al., 2014; Kappenman et al., 2014; Price et al., 2015). Of note, the absence of the significant associations between AB and fearful temperament as well as anxiety in this study does not suggest that threat-related attention processes measured in the dot-probe task are irrelevant to children’s fearful temperament or anxiety development. For example, although the association between the behavioral AB (i.e., reaction time) and fearful temperament was not significant in 9- to-12-year-old children, fearful temperament in that study had been linked to distinct neural activities as responses to threatening stimuli (i.e., greater activation in the
frontolimbic network during incongruent trials than congruent trials) in the dot-probe task, which in turn were associated with a higher level of anxiety. (Fu et al., 2017). In addition, decreased anxiety symptoms were correlated with an augmented amplitude in P2 component in response to faces in the dot-probe task, but not associated with the behavioral AB in 9- to 12- year-old children (Thai et al., 2016). These findings suggest that neural correlates of AB measured in the dot-probe task may provide more reliable and sensitive indicators of threat-related AB than the behavioral measures (Kappenman et al., 2014; Price et al., 2015). Therefore, this study highlights the need for future research to use a multi-method approach to assess threat-related AB including but not limited to psychophysiology and neuroimaging (White et al., 2017).

Fourth, fearful temperament may not unvaryingly lead to AB toward threat, but can also facilitate individuals to avoid threat. The consistent avoidance of threat may represent another abnormal pattern of AB by delaying elaborate processing and habituation to anxiety-provoking stimuli, and thereby is responsible for the onset and maintenance of anxiety (Foa & Kozak, 1986). Perhaps for one group of children, fearful temperament causes an AB toward threats, which is indicated by the positive scores in the dot-probe task, so there is a positive association between fearful temperament and AB scores as well as between AB scores and anxiety. For another group of children, fearful temperament leads to AB away from threats that is indicated by the negative values in the dot-probe task, thereby fearful temperament and anxiety are negatively associated with AB scores. Treating children with atypical AB as a homogeneous group may cancel out the associations between AB and temperament as well as anxiety.

It is worth noting that AB has been demonstrated as a moderator rather than a mediator in the association between fearful temperament and anxiety symptoms (e.g., Nozadi et al., 2016; White et al., 2017). In other words, AB does not explain the association between fearful
temperament and anxiety but performs as a second vulnerability factor, interactively with fearful temperament, in predicting anxiety symptoms. However, as noted above, all of these studies utilized reaction time as a way to assess AB, which might not reflect the accurate role of AB in relation to fearful temperament and anxiety. A multilevel assessment of AB is needed in future research to fully uncover the complex associations among fearful temperament, AB, and anxiety.

Another important reason as to why the associations among fearful temperament, AB, and anxiety were not significant, however, can be because the association is not linear and is moderated by a number of factors. For example, I found in the present study that EC and FA moderated the association between fearful temperament and AB as well as anxiety symptoms.

**Fearful temperament, AB, EC, and anxiety**

My study represented the first to examine how different subtypes of EC moderated the association between fearful temperament and AB as well as anxiety during middle childhood to adolescence. According to the results, all three components of EC moderated the association between fear and anxiety. That is, high AC, IC, and ACT mitigated the adverse effect of fear on anxiety symptoms at a later age. Interestingly, only AC and IC, but not ACT, moderated the association between fearful temperament and AB. Moreover, it is the sustained AB rather than automatic AB that was moderated by AC and IC.

The finding that AC serves as a protective role in children with high fearful temperament is consistent with previous literature reporting that AC attenuated the relation between fearful temperament and children’s internalizing problems (e.g., Oldehinkel et al., 2007; White et al., 2011). My study shed light on the potential mechanism by which AC alleviated the anxiety symptoms by showing that children who had high AC were better able to direct attention away from threat compared with children who had low AC. The greater flexibility in shifting attention
away from threat and in focusing attention on task-related targets regardless of the presence of threatening distractors reduce the vulnerability to anxiety symptoms (Lonigan & Vasey, 2009; White et al., 2011).

Contrary to my hypothesis that fear positively predicted anxiety symptoms when children had high IC, in this study high IC actually protected children from developing anxiety symptoms. Moreover, this study is the first one to show the moderating effect of IC between fearful temperament and AB in childhood and adolescence. Children with high IC were better able to disengage attention away from threat, which might explain the protective effect of IC in against anxiety. According to the efficiency of goal-directed attention modal (Henderson & Wilson, 2017), however, high IC prolongs initial, automatic AB toward threat. The combination of IC and fearful temperament creates an inflexible over-controlled system; thus fearful children with high IC are more likely to get stuck on threatening stimuli and more vulnerable to experience anxiety symptoms. In support of this, high IC increased the risk of anxiety for children with high fearful temperament (White et al, 2011). There are also studies, however, demonstrating the adaptive effect of IC in fearful children’s socioemotional development. For example, in a study that used the same sample of children as the current study but at younger ages, IC was found to reduce the risk of internalizing problems for children who had high fearful temperament and experience increased maternal negative behaviors (Liu et al., 2018).

The inconsistent findings may partly due to the different levels of fearful temperament. Children in my study came from a community sample compared with White and colleagues’ (2011) study, in which only children screened for having extreme patterns of reactivity to auditory and visual stimuli were included. For children with low to moderate levels of fearful temperament as those included in my study, IC may perform as a beneficial factor by helping
children regulate their negative emotions and facilitating better social interactions with parents, teachers, and peers (Eggum-Wilkens et al., 2016; Liu et al., 2018). For children with high fearful temperament, however, the negative effect of IC may exceed its positive influence, thus putting these children at a higher risk of anxiety. More research is needed to examine the role of IC in the development of anxiety in children with different levels of fearful temperament.

An important contribution of the current study was to examine the moderating effect of ACT on the associations between fearful temperament, AB, and anxiety because little is known about the role of ACT in the development of AB and anxiety. Consistent with my hypothesis, fearful temperament positively predicted anxiety only when children had low ACT. ACT refers to the ability to make yourself do the things that you do not want to do. Therefore, fearful children with a high level of ACT are more likely to force themselves to participate in social activities, although doing so can make them feel uncomfortable (Eggum-Wilkens et al., 2016). The increased experiences in social interactions may elevate their thresholds of feeling anxious and provide them opportunities to meet with new friends and to practice their social skills. Therefore, ACT protects fearful children from developing anxiety symptoms.

ACT, however, did not moderate the association between fearful temperament and AB in this study. This is not beyond my expectation as no empirical research so far has reported the effect of ACT on AB. It is possible that ACT does not play an important role in helping fearful children disengage from threat because shifting attention from threat is something they fail to do due to a lack of ability rather than something they do not want to do. What fearful children need are high IC that facilitates them to stop focusing on the threats that are attractive to them and instead switch to target stimuli as well as high AC that helps them fulfill this shifting process. Of note, ACT in this study was measured via maternal reports only, compared with AC and IC that
were assessed with both maternal reports and behavioral tasks. Therefore, it remains a possibility that ACT has a relation to AB but the limitations in measurement covered the association. ACT is the least-studied subtype of EC in the development of anxiety, however, given its relevance to fearful temperament and anxiety symptoms as indicated by the current study, it is critical for future research to use a multi-method approach to further investigate the role of ACT in the development of anxiety and its underlying mechanism.

Interestingly, it is the sustained AB instead of automatic AB that was moderated by AC and IC in this study. This is consistent with what Lonigan and colleagues (2004) suggested that to test the moderating effect of EC on the association between negative temperament and AB, the threatening stimuli should be presented for a certain amount of time (i.e., 1250-1500 ms) to allow EC to play a role. My study represented the first one to directly compare automatic AB and sustained AB and demonstrated the difference between the two types of AB in terms of how they can be altered by EC. Of note, AB was measured in adolescence in this study. EC shows a continually progress across toddlerhood and childhood and reaches adult-like level during adolescence (Gerardi-Caulton, 2000; Luna et al., 2004). Therefore, studies focused on AB at earlier ages may want to consider utilizing AB measured with a longer stimulus presentation (i.e., 1500 ms to 2000 ms) duration to fully capture the effect of EC in younger children.

**Fearful temperament, AB, FA, and anxiety**

Consistent with my hypotheses, FA at age 9 moderated the association between fear at 9 years and adolescent anxiety as well as adolescent AB. Specifically, fear positively predicted anxiety only when children showed concurrent greater right rather than left activation from baseline to task. The finding is consistent with previous studies that examined the moderating effect of FA between fearful temperament and internalizing problems. For example, adolescent
girls high in fearful temperament reported having greater generalized anxiety if they showed greater right than left FA (Lahat et al., 2018). In addition, adolescents who scored high on fearful temperament measures during toddlerhood showed hypersensitivity to errors in a social context at age 12 if they had greater concurrent right FA, compared with having greater left FA (Harrewijn et al., 2019). According to the motivational direction model, right FA is associated with withdrawal motivation (Harmon-Jones & Gable, 2018). Having greater right frontal activity may foster inhibition or social withdrawal of fearful children and exacerbate the negative influence caused by being fearful. Having left FA indicative of a biological motivation to approach, however, may contribute to the resilience process by suppressing the negative disposition, thus reducing the risks of having internalizing problems. Of note, my study represents the first that examined the moderating effect of task-related FA on the association between temperament and anxiety. Compared with resting FA, task-related FA may better capture children’s emotional flexibility in real life where they are likely to encounter and respond to a wide range of situations, thus had higher ecological validity.

Importantly, the current study found that fear predicted AB away from threat for children who showed greater left activation from baseline to task. This finding might suggest that left FA overcomes the maladaptive pattern of AB, thus contribute to the resilience process of anxiety. Left prefrontal cortex has been suggested to exert an inhibitory effect on subcortical affective circuitry, including the amygdala that is involved in threat detection and evaluation (Davidson, 2001). In addition, there is a reciprocal coupling between the basal rate of glucose metabolism in the left anterior cortex and the amygdala based on neuroimaging findings (Abercrombie et al., 1996). For children who have greater left frontal activity, they may be better able to inhibit the
activity of subcortical systems that underlie threat detection and evaluation, thus are less
disturbed by threatening stimuli and are more engaged in task-related goals.

Interestingly, FA moderated the effect of fearful temperament on sustained AB but not
automatic AB in this study. Similarly, FA was related to AB measured with a longer threat
presentation time (i.e., 500 ms) but not with a short presentation time (i.e., 17 ms) in healthy
adults (Pérez-Edgar et al., 2013). The neurophysiological findings may echo the behavioral
findings that threatening stimuli should be presented long enough to permit the full down-
regulation of the prefrontal cortex over the subcortical areas. Previous fMRI studies also
demonstrated different prefrontal cortex and amygdala activities associated with AB that were
measured with short or long stimuli presentation time in clinically anxious adolescence (Monk et
al., 2006; 2008). More studies are needed to further examine the rapid prefrontal cortex and
limbic system processing that underlie both early-stage AB and later-stage AB (Pérez-Edgar et
al., 2013).

Strengths, limitations, and future directions

The current study contributes to the literature in four important ways. First, this study
represents the first to examine the moderating effects of all three components of EC on the
association between children’s fearful temperament and AB as well as anxiety symptoms during
adolescence. AC and IC were measured with both laboratory behavioral tasks and maternal
questionnaires compared with most previous research that exclusively relied on self-reports or
maternal reports (Lonigan & Vasey, 2009; Pavlou et al., 2016; Susa et al., 2014). The findings
provide insight into the roles of AC, IC, and ACT as protective factors against anxiety and the
potential underlying mechanisms. Second, this study is the first to examine how task-related FA
moderated the association between fearful temperament and AB as well as anxiety during middle
childhood to adolescence. It improves our understanding of how greater left brain activation in response to a mild stressor performs as a resilient factor that keeps children from developing anxiety symptoms. Third, I utilized a longitudinal design by using fear, EC, and FA at 9 years to predict AB and anxiety during adolescence, which reveals the longitudinal relations among them and allows potential directional inferences. Of note, however, AB and anxiety were measured concurrently, thus the directionality of the relation between AB and anxiety cannot be evaluated based on the findings from this study. Fourth, I examined the potential anxiety symptoms of a group of typically developing children, which allows us to examine the roles of EC and FA in the general population. The majority of the related research has focused on a selected group characterized by a stronger potential for later psychopathology, such as children selected for extreme fearful temperament (e.g., Buss et al., 2013; White et al., 2011) or parent depression (e.g., Feng et al., 2012). On one hand, studying typically developing children allows the generalization of the findings; on the other hand, the study of processes that contribute to typically developing children’s subsequent disorders, as well as process that mitigate the risk of a disorder, sheds light on the full range of developmental phenomena (Cicchetti & Rogosch, 2002).

Despite the strengths of the current study, the findings should be interpreted in light of several limitations. To begin, although behavioral measures (i.e., reaction time) have been widely used in developmental and clinical literature to assess children’s and adults’ AB, the psychometric properties of behavioral measures of AB have been challenged (Brown et al., 2014; Kappenman et al., 2014; Price et al., 2015). To improve the validity and reliability of AB measures without adversely affecting comparability across studies, it would be ideal to use other measures as a complement of the reaction time-based measurements, such as eye-tracking and
psychophysiological measures, which can detect the continuous eye movements and reveal the underpinning neural activities underlying AB. Second, my sample lacks racial and socioeconomic diversity. The majority of participants are from well-educated Caucasian families. Therefore, finding from this study may not be generalized to other populations. Research with more a diverse sample is needed to capture cultural-differences in the mechanisms underlying children’s anxiety development. Third, EC, AB, and FA were all measured only at one time point. As such, the developmental timing of these mechanisms could not be examined. The effects or the degree of effects of EC, FA, and AB on the development of anxiety are likely to change as the brain continues to develop both structurally and functionally across childhood (Romine & Reynolds, 2005; Welsh & Pennington, 1998). It is important for future longitudinal research to utilize more frequent assessments of EC, FA, and AB to better capture their effects on the expression of anxiety at different ages across development. Fourth, adolescents’ anxiety was measured with RCADS, which assesses both total and different subtypes of anxiety as well as depression. Future work research may want to examine just social anxiety aspects of the RCADS as AB has been found to be particularly associated with social anxiety (Ollendick et al., 2019; That et al., 2019).

Conclusions and implications

In conclusion, the current study adds to the existing literature by examining fearful temperament as an early risk factor for adolescent anxiety symptoms and provides insight into the roles of AB, EC, and FA on the temperament-anxiety link. Different components of EC and FA shape the way fearful temperament influences AB as well as anxiety. Higher levels of AC, IC, ACT, and greater left frontal activation protect children away from developing anxiety symptoms. In addition, Higher levels of AC, IC, and greater left frontal activation facilitate
children to direct attention away from threat, which may explain the resilience effects of them in the expression of anxiety. Interestingly, this study did not find direct associations among fearful temperament, AB, and anxiety during middle childhood to adolescence. Future efforts are needed to investigate the associations among these factors with a multi-method approach and longitudinal design. The current study sheds light on the complex mechanisms that underlie the development of anxiety, which provides guidelines on the screening and intervention services for children at higher risk of anxiety during adolescence.
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https://doi.org/10.1007/s10802-008-9293-x


https://doi.org/10.1016/j.ijpsycho.2007.10.007


https://doi.org/10.1007/s10802-011-9490-x
Table 1

Factor Loadings of AC and IC at age 9

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<th>Variables</th>
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</tr>
<tr>
<td>ANT</td>
<td>.16</td>
<td>.39</td>
<td>.69</td>
</tr>
<tr>
<td>EATQ-attention</td>
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</tr>
<tr>
<td>BRIEF-shift</td>
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</tr>
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<td></td>
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<tr>
<td>Stroop</td>
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<td>BRIEF-inhibit</td>
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</table>

Note. AC = attentional control; IC = inhibitory control; ANT = Attention Network Test; EATQ = Early Adolescent Temperament Questionnaire; BRIEF = Behavior Rating Inventory of Executive Function.
Table 2

Descriptive Statistics of Demographic and Study Variables

<table>
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<th>Variable</th>
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<th>SD</th>
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</tr>
<tr>
<td>3. Maternal working hours/week</td>
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</tr>
<tr>
<td>2. Fear_9</td>
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<td>3. AC composite_9</td>
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<tr>
<td>16. Anxiety_adolescent</td>
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<td>86.04</td>
<td>9.21</td>
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</table>

Note. AC = Attentional control, IC = Inhibitory control, ACT = Activation control, ANT = Attention Network Test; EATQ = Early Adolescent Temperament Questionnaire; BRIEF = Behavior Rating Inventory of Executive Function, FA = Frontal activation from baseline to task, AB = Attention biases. The scores in the table represent the original scores without standardizing. Maternal education, 1 = Grade school, 2 = Some high school, 3 = high school graduate, 4 = some college or 2-year college, 5 = 4-year college graduate, 6 = Master’s degree, 7 = Ph.D./M.D. or other doctoral degree. Maternal working hours/week, 0 = does not work, 1 = less than 10 hours, 2 = between 10 and 20 hours, 3 = between 30 and 40 hours, 4 = over 30 hours.
**Table 3**

*Bivariate Associations Among Variables of Interest*

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*Note. AC = Attentional control, IC = Inhibitory control, ACT = Activation control, ANT = Attention Network Test; EATQ = Early Adolescent Temperament Questionnaire; BRIEF = Behavior Rating Inventory of Executive Function, FA = Frontal activation from baseline to task, AB = Attention biases. The scores in the table represent the original scores without standardizing. *p < .05*
Table 4

*Results of the Path Model for Fearful Temperament, Attentional Control, Automatic AB (500 ms), and Anxiety Symptoms During Adolescence*

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<th>Mediator: Automatic AB</th>
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<td>Sex</td>
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<td>Fear * AC</td>
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<td>AB</td>
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*Note. AC = Attentional control, AB = Attention biases. *p < .05.
Table 5

Results of the Path Model for Fearful Temperament, Attentional Control, Sustained AB (1250 ms), and Anxiety Symptoms During Adolescence

<table>
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<th></th>
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<tr>
<td>Fear * AC</td>
<td>-0.83</td>
<td>0.36</td>
<td>-2.35*</td>
<td>-0.85</td>
<td>0.35</td>
<td>-2.40*</td>
</tr>
<tr>
<td>AB</td>
<td>0.07</td>
<td>0.10</td>
<td>0.66</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dependent Variable: Anxiety_Adolescent</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Note. AC = Attentional control, AB = Attention biases. *p < .05.
Table 6

Results of the Structural Equation Model for Fearful Temperament, Inhibitory Control, Automatic AB (500 ms), and Anxiety Symptoms During Adolescence

<table>
<thead>
<tr>
<th>Mediator: Automatic AB</th>
<th>Dependent Variable: Anxiety_ Adolescent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>-5.53</td>
</tr>
<tr>
<td>SE</td>
<td>1.81</td>
</tr>
<tr>
<td>t</td>
<td>-3.05*</td>
</tr>
<tr>
<td><strong>Fear</strong></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>-3.70</td>
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<tr>
<td>SE</td>
<td>3.22</td>
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<td>t</td>
<td>-1.15</td>
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<tr>
<td>SE</td>
<td>8.48</td>
</tr>
<tr>
<td>t</td>
<td>-0.02</td>
</tr>
<tr>
<td><strong>Fear * IC</strong></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>0.01</td>
</tr>
<tr>
<td>SE</td>
<td>2.90</td>
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<tr>
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<td>-4.01</td>
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<tr>
<td><strong>AB</strong></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>0.04</td>
</tr>
<tr>
<td>SE</td>
<td>0.05</td>
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<tr>
<td>t</td>
<td>0.75</td>
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</table>

Note. IC = Inhibitory control, AB = Attention biases. *p < .05.
Table 7

Results of the Structural Equation Model for Fearful Temperament, Inhibitory Control, Sustained AB (1250 ms), and Anxiety Symptoms During Adolescence

<table>
<thead>
<tr>
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<th>t</th>
<th>b</th>
<th>SE</th>
<th>t</th>
</tr>
</thead>
<tbody>
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<td><strong>Mediator: Sustained AB</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
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<td>1.73</td>
<td><strong>-3.35</strong></td>
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<td></td>
</tr>
<tr>
<td>Fear</td>
<td>-1.66</td>
<td>2.94</td>
<td>-.56</td>
<td>4.96</td>
<td>1.39</td>
<td><strong>3.58</strong></td>
</tr>
<tr>
<td>IC</td>
<td>13.76</td>
<td>6.57</td>
<td><strong>2.09</strong></td>
<td>9.93</td>
<td>3.76</td>
<td><strong>2.64</strong></td>
</tr>
<tr>
<td>Fear * IC</td>
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<td><strong>-2.11</strong></td>
<td>-3.90</td>
<td>1.52</td>
<td><strong>-2.57</strong></td>
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<td>AB</td>
<td>.03</td>
<td>.05</td>
<td>.59</td>
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</tr>
</tbody>
</table>

*Note. IC = Inhibitory control, AB = Attention biases. *p < .05.
Table 8

Results of the Path Model for Fearful Temperament, Activation Control, Automatic AB (500 ms), and Anxiety Symptoms During Adolescence

<table>
<thead>
<tr>
<th></th>
<th>β</th>
<th>SE</th>
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<th>Mediator: Automatic AB</th>
<th>β</th>
<th>SE</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-6.67</td>
<td>1.81</td>
<td>-3.68*</td>
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<tr>
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<td>-.11</td>
<td>.10</td>
<td>-1.07</td>
<td></td>
<td>.36</td>
<td>.10</td>
<td>3.62*</td>
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<tr>
<td>ACT</td>
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<td>.38</td>
<td>-.10</td>
<td></td>
<td>.70</td>
<td>.34</td>
<td>2.03*</td>
</tr>
<tr>
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<td>.32</td>
<td></td>
<td>-.72</td>
<td>.36</td>
<td>-2.02*</td>
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<tr>
<td>AB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.08</td>
<td>.11</td>
<td>.68</td>
</tr>
</tbody>
</table>

*Note. ACT = Activation control, AB = Attention biases. *p < .05.
Table 9

Results of the Path Model for Fearful Temperament, Activation Control, Sustained AB (1250 ms), and Anxiety Symptoms During Adolescence

<table>
<thead>
<tr>
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<th>Mediator: Sustained AB</th>
<th>Dependent Variable: Anxiety_Adolescent</th>
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</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
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</tr>
<tr>
<td>β</td>
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<td>.36</td>
</tr>
<tr>
<td>SE</td>
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<td>t</td>
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<td>3.61*</td>
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<tr>
<td><strong>Fear</strong></td>
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<td></td>
</tr>
<tr>
<td>β</td>
<td>-.23</td>
<td>-.68</td>
</tr>
<tr>
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<td>-.67</td>
<td>-2.02*</td>
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<tr>
<td><strong>ACT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>β</td>
<td>.12</td>
<td>.68</td>
</tr>
<tr>
<td>SE</td>
<td>.32</td>
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<tr>
<td>β</td>
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<td>.10</td>
</tr>
<tr>
<td>SE</td>
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Note. ACT = Activation control, AB = Attention biases. *p < .05.
Table 10

Results of the Path Model for Fearful Temperament, Frontal EEG Asymmetry, Automatic AB (500 ms), and Anxiety Symptoms During Adolescence

<table>
<thead>
<tr>
<th></th>
<th>β</th>
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<th>β</th>
<th>SE</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mediator: Automatic AB</td>
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<td></td>
<td></td>
<td>Dependent Variable: Anxiety Adolescent</td>
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</tr>
<tr>
<td>Sex</td>
<td>-6.08</td>
<td>1.83</td>
<td>-3.32*</td>
<td>Fear</td>
<td>-.10</td>
<td>.11</td>
</tr>
<tr>
<td>FA</td>
<td>.02</td>
<td>.34</td>
<td>.07</td>
<td>.77</td>
<td>.33</td>
<td>2.35*</td>
</tr>
<tr>
<td>Fear * FA</td>
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<td>.10</td>
<td>-.84</td>
<td>.36</td>
<td>-2.36*</td>
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<tr>
<td>AB</td>
<td>.09</td>
<td>.11</td>
<td>.84</td>
<td></td>
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</tr>
</tbody>
</table>

Note. FA = Frontal activation from baseline to task, AB = Attention biases. *p < .05.
Table 11

*Results of the Path Model for Fearful Temperament, Frontal EEG Asymmetry, Sustained AB (1250 ms), and Anxiety Symptoms During Adolescence*

<table>
<thead>
<tr>
<th></th>
<th>β</th>
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<th>t</th>
<th>β</th>
<th>SE</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mediator: Sustained AB</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>Dependent Variable: Anxiety_ Adolescent</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>-6.34</td>
<td>1.93</td>
<td>-3.29*</td>
<td>Fear</td>
<td>-.16</td>
<td>.10</td>
</tr>
<tr>
<td>FA</td>
<td>.56</td>
<td>.35</td>
<td>1.60</td>
<td>.74</td>
<td>.33</td>
<td>2.24*</td>
</tr>
<tr>
<td>Fear * FA</td>
<td>-.74</td>
<td>.38</td>
<td>-1.96*</td>
<td>-.79</td>
<td>.36</td>
<td>-2.21*</td>
</tr>
<tr>
<td>AB</td>
<td>.04</td>
<td>.10</td>
<td>.33</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* FA = Frontal activation from baseline to task, AB = Attention biases. *p < .05.
Figure 1

*Conceptual Representations of the Hypothesized Associations Among Fear, AB, and Anxiety*
Figure 2

Conceptual Representations of the Hypothesized Associations Among Fear, AB, AC, and Anxiety

Note. AC = Attentional control, AB = Attention biases, ANT = Attention Network Test; EATQ = Early Adolescent Temperament Questionnaire; BRIEF = Behavior Rating Inventory of Executive Function.
Figure 3
Conceptual Representations of the Hypothesized Associations Among Fear, AB, IC, and Anxiety

Note. IC = Inhibitory control, AB = Attention biases, EATQ = Early Adolescent Temperament Questionnaire; BRIEF = Behavior Rating Inventory of Executive Function.
Figure 4

Conceptual Representations of the Hypothesized Associations Among Fear, AB, ACT, and Anxiety

Note. ACT = Activation control, AB = attention Biases.
Figure 5

Conceptual Representations of the Hypothesized Associations Among Fear, AB, FA, and Anxiety

Note. FA = Frontal activation from baseline to task, AB = Attention biases.
Figure 6

Attention Control Moderated the Association Between Fear at 9 Years and Sustained Attention Biases During Adolescence

Note. AC = Attentional control.
Figure 7  

Attention Control Moderated the Association Between Fear at 9 Years and Adolescent Anxiety Symptoms with Sustained Attention Biases Being Controlled  

Note. AC = Attentional Control.
Figure 8

Inhibitory Control Moderated the Association Between Fear at 9 Years and Sustained Attention Biases During Adolescence

Note. IC = Inhibitory Control.
Figure 9

*Inhibitory Control Moderated the Association Between Fear at 9 Years and Adolescent Anxiety Symptoms with Sustained Attention Biases Being Controlled*

Note. IC = Inhibitory Control.
Activation Control Moderated the Association Between Fear at 9 Years and Adolescent Anxiety Symptoms with Sustained Attention Biases Being Controlled

Note. ACT = Activation Control.
Figure 11

Frontal EEG Asymmetry Moderated the Association Between Fear at 9 Years and Sustained Attention Biases During Adolescence

Note. FA = = Frontal activation from baseline to task.
Frontal EEG Asymmetry Moderated the Association Between Fear at 9 Years and Adolescent Anxiety Symptoms with Sustained Attention Biases Being Controlled

Note. FA = = Frontal activation from baseline to task.
DATE: 08/13/2019
TO:   Martha Ann Bell, PhD
FROM: Raffaella Hart, MS, CIP, BRANY SBER IRB (IRB00010793)

SUBMISSION TYPE: SBER-Initial Review (Event ID# 156911)
PROTOCOL NUMBER:  19-030-568 / 19-352
STUDY TITLE: Psychobiology of Cognitive Development in Early Adolescence

IRB ACTION:  Approved - SBER

APPROVAL DATE: 08/13/2019
EXPIRATION DATE: Non-Expiring
REVIEW TYPE: Expedited Initial Review

Thank you for your submission for the above-referenced study.

1. **BRANY SBER IRB Determination**
   Your submission was APPROVED by the BRANY SBER IRB via expedited review under categories: 4, 6, 7. This approval requires that all procedures and activities are performed in accordance with relevant state and local law (including tribal law, when applicable).

2. **Submitted Documents**
   a. SBER Study Application xForm (signed 7/10/19)
   b. Email (8/12/19) indicating application for Certificate of Confidentiality was submitted
   c. Parent Consent Form – Questionnaire Only Group (Version A)
   d. Assent Form – Questionnaire Only Group (Version A)
   e. Parent Consent Form – Lab Visit Group (Version A)
   f. Assent Form – Lab Visit Group (Version A)
   g. Abstract (BRANY Stamp 8/13/19)
   h. Protocol #19-352 - Version 1.0 - 6/5/19, including all data collection instruments listed on p. 12, 13, and 14.
   i. 19-325 Protocol Script and Materials (BRANY Stamp 8/13/19)
   j. 5 videos: (1) Cognitive Reappraisal Instructions, (2) Emotion Suppression Instructions, (3) My Girl, (4) The Champ, and (5) Vanilla Baseline
   k. Recruitment Email: Adolescent Lab Visits (BRANY Stamp 8/13/19)
   l. Recruitment Email: Adolescent Q-Only Families
   m. Recruitment Facebook: Adolescent
   n. Recruitment Letter: Adolescent Lab Visits
   o. Recruitment Letter: Adolescent Q-Only Families

   *Modifications are in accord with those required by the IRB, and were incorporated as indicated in the enclosed redlined version.*

3. **Provisions of BRANY SBER IRB Approval**
a. This study requires consent/permission of subjects to be obtained. You must continue to monitor the subject’s willingness to be in the study for the duration of the subject’s participation. Only use the current IRB-approved and stamped forms in the consent process. Each subject must receive a copy of his/her signed consent/permission/assent document. Consent forms signed by subjects in this study must be kept by the Principal Investigator for at least 3 years, or longer if required by your institution.

b. All research must be conducted in accordance with this approved submission. Any changes to the approved study must be reviewed and approved by the BRANY SBER IRB prior to implementation, except when necessary to eliminate an apparent immediate hazard to the subject.

c. Unanticipated problems (including serious adverse events, if applicable) must be reported to BRANY SBER IRB within 5 days of discovery using Form IRB-4 (Reporting Form for Events that Require Prompt Reporting to the IRB).

d. Any complaints or issues of non-compliance must be immediately reported to BRANY SBER IRB.

4. Inclusion of Minors
Inclusion of minors in the study is acceptable in accordance with 45 CFR 46.404. Parental permission and minor assent is obtained in accordance with 45 CFR 46.408.

a. Assent must be sought, obtained, and documented from all minor subjects capable of giving it. Subjects ages 7-17 years should document assent by signing a separate assent form.

b. Permission must be sought, obtained, and documented from one parent or legal guardian.

5. Study Personnel
The following study personnel have been approved to participate in this research project.

a. Martha Ann Bell, PhD
b. Ran Liu
c. Tatiana Garcia Meza
d. Leslie Patton

6. Non-Expiring IRB Approval Period
This study was reviewed under the Revised Common Rule (2018 requirements) and therefore does not require continuing review in accordance with 45 CFR 46.109(f)(1)(i).

However, BRANY SBER IRB requires you "check in" at least annually to ensure your study status is up to date and in compliance. Your Annual Report to BRANY IRB is due on 08/12/2020. If your research is completed before then, you must submit a notification of study closure to BRANY SBER IRB (use the xForm called: SBER-Study Status Change (Closed/Enrollment Closed)).

If you have any questions or require any additional information, please call me at 516-470-6909 or send an email to me at rhart@brany.com. Thank you.