ABSTRACT

Title of Dissertation:	ATTENTION BIAS TOWARD THREAT ACQUISITION: A DEVELOPMENTAL FRAMEWORK
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The primary goal of this study was to examine possible differences in threat bias acquisition across development. The current study aimed to 1) examine if threat bias could altered in 8, 12, and 18-year old children and explore possible age-related differences in threat bias acquisition 2) examine age-related differences in the relations between bias change and stress reactivity 3) examine pubertal development and its possible relations to bias change and stress reactivity and 4) explore temperamental traits and their possible relation to threat bias acquisition. To address these aims, the current study utilized an attention bias modification (ABM) with three age groups (8-year-old, 12-year-old, and 18-year-old children) to train attention allocation toward threat-related stimuli. After training, participants underwent a stress task and were assessed on emotional reactivity to stress. Data were also collected on pubertal development, trait anxiety, trait fearfulness, and social sensitivity.

Overall, the results indicated that the training paradigm was partially successful in altering children's threat bias, however, age was related to bias change. Results indicated

that participants, regardless of age group, responded faster on the dot-probe task over time, suggesting the training procedure increased vigilance to threat. Results did not show a main effect of bias change from pre-training to post-training; however, there was a significant age group difference in threat bias acquisition. The 8-year old group displayed a greater threat bias change than did the 18-year old group. In partial support of the hypotheses, findings suggested that there were some group differences between stress reactivity and bias change. As well, decreases in anxiety reported stress reactivity after completion of a speech task were associated with more advanced pubertal development. Lastly, while pubertal development scores correlated with threat bias acquisition, self-reported temperamental trait characteristics did not relate to threat bias acquisition. While there is a clear need for the continued study of ABM across development, the current study is one of the first to show age differences in threat bias acquisition and its' relations to stress reactivity and pubertal development.

ATTENTION BIAS TOWARD THREAT ACQUISITION: A DEVELOPMENTAL FRAMEWORK

By

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Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2014

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Chapter 1. Introduction

Anxious individuals often preferentially allocate their attention toward threatening information in the environment over non-threatening stimuli, a pattern not detected in non-anxious individuals (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). This bias, referred to as an attention bias toward threat, is implicated in the development and maintenance of anxiety (Mathews & MacLeod, 2002; Mogg & Bradley, 1998). This link has been established through both longitudinal (Perez-Edgar et al., 2010; Perez-Edgar et al., 2011) and experimental work (Eldar, Ricon, & Bar-Haim, 2008; Mathews & MacLeod, 2002). Experimental studies have induced an attention bias toward threat in non-anxious individuals and demonstrated subsequent increases in susceptibility to anxiety and/or depression during a stressful event (Eldar, et al., 2008; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). However, little is known about how threat acquisition changes over development. Specifically, there is a paucity of developmental literature on the behavioral processes involved in the acquisition of an attention bias toward threat and how these processes contribute to emotional vulnerability.

Because most chronic adult anxiety disorders have roots in childhood, it is important to examine the way in which attention bias and anxiety interact throughout development (D. S. Pine, 2007). Available cross-sectional data demonstrate an association between attention bias and anxiety across various age groups, from preschool through adulthood (Martin, Horder, & Jones, 1992; Roy et al., 2008; A. Waters, Henry, Mogg, Bradley, & Pine, 2010; A. Waters, Lipp, & Cobham, 2000). Findings in adults suggest that the ease with which an attention bias toward threat is acquired positively predicts trait anxiety as a result of stress (Clarke, Macleod, & Shirazee, 2008). Therefore, the rate at which a threat bias is learned can predict individual differences in stress reactivity. While bias acquisition can potentially be an important predictor of later anxiety, little is known about developmental differences in attention bias toward threat acquisition.

The period of adolescence is of particular importance when examining developmental changes of threat bias acquisition. This developmental period has been considered a time of heightened vulnerability for the onset and intensification of anxiety problems (E. Leen-Feldner, Reardon, Hayward, & Smith, 2008; Reardon, Leen-Feldner, & Hayward, 2009). Adolescence and the onset of puberty marks a time of major hormonal, physiological, physical and social changes. Since puberty is a normative experience for youth and not all pubescent youth experience anxiety, there is growing evidence that puberty marks a "critical period" for children with pre-existing vulnerabilities (i.e. Caspi & Moffitt, 1991; E. W. Leen-Feldner et al., 2006). The ease at which youth acquire an attention bias toward threat may reflect one type of anxiety vulnerability that may be exacerbated by later pubertal status.

Moreover, there may be certain populations in which attention bias toward threat is more likely to lead to anxiety problems. One such "risky" population is of children with behaviorally inhibited or fearful temperament. Longitudinal research has shown that biases early in life may moderate risk for later anxiety in behaviorally inhibited children (e.g. Perez-Edgar, et al., 2010; Perez-Edgar, et al., 2011). Youth are heavily influenced by their peers and the degree to which adolescents worry about fitting in and being socially rejected is another potential vulnerability that is particularly heightened in adolescence and can lead to distress. Experimental work examining how the modulation of attention bias toward threat relates to temperament and social sensitivity may help characterize children at risk for later anxiety.

Attention bias modification (ABM) toward threat has been found to alter anxiety and stress reactivity. While ABM has been extensively studied in adults, few studies have used ABM with children and no study has examined developmental changes of threat bias acquisition. The first goal of the current study was to examine age related differences in acquisition of an attention bias toward threat. A second goal was to examine the relations at each age between attention bias to threat and stress reactivity. A third goal was to examine the relations between pubertal development and bias change and between pubertal development and stress reactivity. A fourth goal was to examine the relations within each age group between temperamental (trait fearfulness and social sensitivity) characteristics and acquisition of an attention bias to threat. These four goals were examined by:

1) Running ABM toward threat with three age groups to examine if it was successful in altering bias scores and whether bias change differed between age groups.
2) Examining how bias acquisition related to stress reactivity for each of the different age groups.
3) Examining puberty scores and their possible relations to threat bias acquisition and stress reactivity.
4) Examining temperamental traits within each age group and their possible relations to threat bias acquisition.

Chapter 2: Background

This chapter will cover the basic methodological and conceptual background of attention bias toward threat and will then explore the effects of ABM. First, the chapter will review the theoretical background of attention bias and anxiety. Second, the literature on attention bias toward threat and anxiety, with a particular emphasis on attention biases in children will be reviewed. Third, the developmental period of adolescence will be discussed as a "sensitive period". Lastly, the literature on the use of ABM, with a focus on training toward threat will be reviewed.

2.1 Theories of Attention Bias

Fear and Attention: Prepared-Learning Theory

An underlying cause of anxiety is thought to involve biased cognitive processing of the fear system. Fear is defined as a physiological and behavioral response to a threatening stimulus (Armony & Dolan, 2002). According to the prepared learning view, humans and non-human primates have a predisposition to associate fear with potential threat (Ohman & Mineka, 2001; Seligman, 1970). It has been proposed that the evolutionary advantage of fear is that it facilitates attention-shifting in the presence of danger or potential danger (e.g. Georgiou et al., 2005). For example, if a fox approaches a rabbit while the rabbit is building a nest, it is important for the rabbit to be able to quickly allocate attention to the predator in order to best respond to the potential danger. Humans also encounter situations in which fear detection, attention allocation to possible sources of threat, and fear responses, behavioral (fight or flight) and physiological (increased heartbeat, rapid breathing, muscle tension), can help an individual appropriately respond to danger in their environment.

While fear can serve an adaptive purpose, some individuals experience fear to non-threatening stimuli. These individuals often develop cognitive distortions, which are maladaptive behavioral and physiological responses resulting from biased cognitive processes, such as attention bias toward threat (Leitenberg, Yost, & Carroll-Wilson, 1986). This can lead to unnecessary anxiety and increased risk for developing an anxiety disorder (Williams, Watts, MacLeod, & Mathews, 1988). Anxiety is often associated with the uncertainty of the expectancy of threatening stimuli (Cannistraro & Rauch, 2003). It involves general distress elicited by less explicit or ambiguous stimuli, whereas fear is triggered by explicitly threatening stimuli and results in escape or avoidance (Lang, Davis, & Ohman, 2000).

Research has suggested that different processing biases in mildly stressful situations are associated with vulnerability to anxiety (Mathews & MacLeod, 2002). In a stressful situation, such as a job interview for adults or the first day of school for children, anxious individuals are likely to use a "vigilant" processing mode, in which mildly threatening cues are quick to capture their attention. The stream of information these individuals take in is often related to negative outcomes and potential threat and, in turn, increases state anxiety. The same stressor in non-anxious people is not as likely to lead to "vigilant" processing, so these individuals may be able to ignore the mild threats through an "avoidant" processing mode. Of course, non-anxious individuals adaptively utilize vigilant processing modes. In situations involving high danger and threat, such as experiencing a burglar break into one's house, it is highly adaptive and beneficial to change from avoidant processing to "vigilant processing". It is thought that the discrepancy between anxious and non-anxious individuals' "vigilant processing" is due in part to anxious individuals having a lower threshold for vigilant response to threatening stimuli (Mathews & MacLeod, 2002).

Social Information Processing Models

Anxious populations routinely process incoming information from their environment differently than non-anxious individuals (Daleiden & Vasey, 1997). Information-processing models explain the steps in which information is modulated and manipulated through processes of the cognitive system. The information-processing model proposed by Dodge (Crick & Dodge, 1994; Dodge, 1991) described six stages: encoding, interpretation, construction, response access, and enactment. The encoding stage occurs when resources are first allocated to automatically or consciously selected information from the environment. Meaning is then given to this information during the interpretation stage. During construction, the individual decides whether to keep his existing goal or select a new goal depending on situational demands. Goals are "focused arousal states that function as orientations toward producing particular outcomes" (Crick & Dodge, 1994 p.76). In the response access stage, memories of previous responses are retrieved and new responses are generated based on the current social cues. During this phase, all possible responses are assessed in order for the individual to pick the response that would most likely aid in achieving his goal. The last stage, enactment, describes the final response selection. Although many stages influence each other in a bi-directional fashion, they typically occur in the linear order listed above. Attention bias is a critical process involved in this model.

Rubin and Krasnor (1986) proposed a similar information processing model but for the automaticity of thinking required for social competence in children. The first step in this model involves selecting a social goal. Then, children examine the “task environment” in which they consider contextual factors that can influence their goals. The next step in the model is to access and select strategies to achieve the desired goal. Once selected, the strategy is implemented and the outcome of the situation is judged on successfulness. If the social attempt was deemed a failure then adapted goals and strategies can be implemented. These processes are heavily dependent on how the child interprets and views the environment since their goals are heavily based on the context.

More recently, the Posner model of attention was developed to describe three types of attention related to processing: alerting, orienting, and executive attention (e.g. M.I. Posner, 1992; M. I. Posner, 1995; M. I. Posner & Petersen, 1990; Rothbart & Posner, 2001). The alerting system involves having an alert state in order to be able to process priority stimuli in the environment. Orienting describes the selection of certain environmental stimuli in which to attend. Lastly, the executive attention system involves the voluntary control of attention and regulation. This proposal most heavily focuses on Posner’s orientating system.

The relations between attention bias toward threat and the orienting system of Posner’s model of attention have been debated. It is unclear as to whether attention biases are due to the rapid capture of attention toward threat, to a delay in disengaging from threatening stimuli or a combination of both. Recent studies have tried to examine how orienting processes relate to biases in anxious populations (i.e. Carlson & Reinke, 2008; E. H. Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2004; E. H. W. Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006). However, findings have yielded mixed results (see Kirwan, White, & Fox, 2011 for review). For example, while Koster and colleagues (2006) found that high trait anxious participants' attention bias toward threat was driven by difficulties in disengagement from threat, Carlson and Reinke (2008) found that facilitated orienting toward threat, and not disengagement, drove the attention bias findings. It may be a combination of rapid orienting and difficulty disengaging from threat that leads to attention biases.

Biased Competition Model of Attention

Desimone and Duncan (1995) developed the *biased competition model*. In order to best understand this model it is important to consider two phenomena associated with visual attention. The first is that there is limited capacity for how much information can be processed from the visual system. The second phenomenon is selectivity, and describes how unwanted information is filtered out. In sum, information in the environment compete for processing beyond the retina but this competition is biased to stimuli that are more relevant to behavior (Desimone & Duncan, 1995).

This model further illustrates that two factors influence selectivity of information to be processed: bottom-up biases and top-down biases (Desimone & Duncan, 1995). Bottom-up biases involve neural mechanisms in the visual system and are influenced by sensory information such as stimulus size, novelty and contrast. For example, a brightly colored stimulus is more likely to win processing resources than a dull colored stimulus (Treisman & Gormican, 1988). Top-down biases, on the other hand, allow attention to be focused on information relevant to current behavior (Desimone & Duncan, 1995). For example, the accuracy and detection speed of a stimulus is increased if the stimulus is presented in the location where attention was already directed. The frontal and parietal cortices are involved in top-down control. Both bottom-up and top-down biases influence the competition for processing resources among stimuli.

There has been recent debate on the role stimulus valence plays in attentional processing (Pessoa, 2005). Some researchers argue that emotional stimuli can be processed automatically and thus without attention (i.e. Ohman, Esteves, & Soares, 1995; Vuilleumier, Armony, Driver, & Dolan, 2001). This is supported by studies that have found increased amygdala activity, a brain structure typically activated by fearful stimuli, for tasks that require participants to attend to non-emotional stimuli and not to presented emotional stimuli (Vuilleumier, et al., 2001). This view is also supported by studies that show amygdala activation to masked fear-related stimuli (i.e. Morris, Ohman, & Dolan, 1998; Whalen et al., 1998). These masked and unattended stimuli are thought to be processed unconsciously, and it is concluded that fear can be processed automatically and through fast subcortical brain circuitry.

The claim for the automatic processing of emotional stimuli has been recently disputed by studies that show that attention is a prerequisite for processing emotional stimuli, and thus not automatic. Pessoa and colleagues (2002) conducted an imaging study to examine emotional processing in a competing task with a high attentional load. The task involved the presentation of a fearful, happy or neutral face in the center of a screen and bars in the left and right periphery. In the attended trials condition, subjects had to indicate whether the face was male or female and in the unattended trials, they had to indicate whether the bars had the same or different orientations. Results indicated that brain regions that respond differentially to emotional stimuli, including the amygdala, only responded to the emotional faces during the attend trials (Pessoa, McKenna, et al., 2002). It was concluded that the attend bars condition exhausted attentional resources such that the emotional faces could not be processed. The authors also suggested that the processing of non-attended emotional stimuli in previous studies, such as that by Vuilleumier and Armony (2001), may be due to using tasks that are not as effective in manipulating attention.

Studies have also found discrepant findings in processing of masked emotional stimuli. For example, Phillips and colleagues (2004) did not find amygdala response to masked unaware emotional conditions. The contrasting findings may be explained by recent work that has found individual differences in the detection of masked emotional stimuli (Pessoa, Japee, & Ungerleider, 2005). In this study an emotional stimulus, a fearful face, was backward masked by a neutral face. The presentation time of the fearful face varied parametrically and subjects responded whether they perceived fear or no fear, thus allowing for the examination of individual differences in visual awareness. Results indicated a great deal of variability in participants' detection sensitivity of fear stimuli. In contrast with previous beliefs about masking, 64% of participants reliably detected target stimuli masked at 33 ms, and two participants were able to detect in stimuli masked as short as 17 ms (Pessoa, et al., 2005). These findings suggest that studies examining the attentional processing of masked emotional stimuli must first take individual differences of threat detection into account before conclusions can be made.

These studies suggest that the neural processing of emotional faces requires attention, thus emotional processing is not automatic but requires top-down control. Therefore, based on the bias competition model of attention, while emotional stimuli can bias attention, stimulus valence must still compete for processing (Pessoa, Kastner, &

Ungerleider, 2002). Similarly to the individual differences found in the ability for some participants to detect masked emotional stimuli, there are individual differences in biases of attention toward threat.

2.2 Attention Bias Measurement and Populations

Attention selectivity refers to the degree to which attention is focused on specific cues at the expense of not attending to other cues (Eimer, 1998). Clinical and non-clinical high trait anxious persons tend to have an attention bias toward threat, in which attention is selectively focused on threat-related stimuli over non-threatening stimuli (Bar-Haim, et al., 2007).

Research has examined how different types of anxiety relate to attention bias toward threat. State anxiety refers to one's current feelings of anxiety, whereas trait anxiety refers to how anxious one generally feels. Studies examining the influence of state and trait anxiety on attention biases have yielded mixed results. Some researchers have suggested that trait and state anxiety interact in their contribution to attention bias toward threat (Broadbent & Broadbent, 1988), whereas others suggest that either state or trait anxiety can produce attention biases (Mogg, Mathews, Bird, & Macgregor-Morris, 1990). The differences in the effects of state versus trait anxiety on attention bias remain unclear. One objective of the present chapter is to explore the relations between attention bias toward threat and anxiety.

In addition to the association between anxiety and attention bias, there is also a relation between attention bias and stress reactivity. A link has been established between an individual's vulnerability to stress and how threatening information is processed: individuals who direct their attention toward threat in their environment react more negatively to environmental stress than those without this bias (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). The converse relations has also been found in which individuals that readily acquire an attention bias to threat are more vulnerable to experiencing increased trait anxiety in response to prolonged stress (Clarke, MacLeod, & Shirazee, 2008).

Biases of selective attention toward threat are typically examined by using paradigms such as the emotional Stroop and dot-probe tasks. When anxious participants are instructed to quickly respond to a specific type of emotionally neutral stimulus or to a specific stimulus attribute, they often show slower reaction times and increased error rates when the target stimulus is simultaneously presented with task-irrelevant threat-related stimuli (e.g. Yiend & Mathews, 2001). For example, in emotional Stroop tasks, participants are instructed to name the color of a presented word. Anxious participants show greater interference when naming the color of threatening words than when naming the color of non-threatening words (R.J. McNally, 1996). These results have been found for participants with specific phobias (e.g. Watts, McKenna, Sharrock, & Trezise, 1986), social phobia (SP) (e.g.Hope, Rapee, Heimberg, & Dombeck, 1990), generalized anxiety disorder (GAD) (e.g. Mathews & MacLeod, 1985), obsessive-compulsive disorder (OCD) (e.g. Foa, Ilai, Mccarthy, Shoyer, & Murdock, 1993) and panic disorder (R. J. Mcnally, Riemann, & Kim, 1990). Although the Stroop paradigm is a widely used task, it has limitations as a measure of attentional bias (R.J. McNally, 1996). It cannot measure selective attention because both the color and word cue are of the same space and cannot be differentiated (E. Fox, 1993). In the Stroop, participants attend to the same stimulus but may be distracted by certain features of that stimulus, whereas presenting target and distracting stimuli in separate locations allows participants to visually attend to one stimulus if attending to threat and another if attending to neutral. Thus, making it easier to distinguish attention between the two stimuli. A second limitation is that the task cannot be used to determine the cognitive processes that interfere with color naming.

The dot-probe paradigm was developed to avoid some of the limitations of previous methods in the examination of attention biases (MacLeod, Mathews, & Tata, 1986). It requires a neutral response (button press) to a neutral stimulus (probe) so biases seen in reaction time are a result of selective attention. The task also allows investigators to examine whether an individual's response to a cue can be impaired or facilitated based on the location of the threatening stimuli relative to the probe (MacLeod, et al., 1986). The task involves the simultaneous presentation of two stimuli, one threatening and one neutral. After their offset, a probe appears in the location previously occupied by one of the stimuli. Participants are instructed to respond as quickly as possible to a specific characteristic of the probe. Reaction times to the probe are used to examine attention allocation, with faster response times to the attended versus unattended stimulus. Participants with an attentional bias toward threat respond faster to the probes located behind a previously threat-related stimulus as opposed to a neutral stimulus. Studies using the dot-probe paradigm have suggested that anxious individuals have an attention bias toward threat (Bar-Haim, et al., 2007; MacLeod, et al., 1986). While the dot-probe paradigm provides a measure of attention bias, it does not differentiate whether the reaction time bias is due to faster engagement to the threatening stimuli or difficulty disengaging from the stimuli.

In order to explore which aspects of attention are affected by threat-related stimuli, research has also examined whether threat distracters and subliminal threats have effects on attention. Anxious individuals continue to show a bias toward threat when threat stimuli must be ignored in order to complete a task. For example, anxious individuals take longer to look for a neutral target if the target is surrounded by threat-related distracters (Mathews, May, Mogg, & Eysenck, 1990). Additionally, anxious individuals show great vigilance toward backward-masked threat-related stimuli despite being unable to identify these stimuli (Mogg & Bradley, 1998).

Research has well established the concept that most chronic adult disorders have roots in childhood and, more specifically, that there are relations between pediatric and adult anxiety (D. S. Pine, 2007). The study of specific factors underlying childhood anxiety is of extreme importance because it may help inform treatments to reduce long term or reoccurring anxiety problems. There has been growing work on social information processing in children.

Pine and colleagues discussed three developmental positions on the relations between attention bias and anxiety (D. Pine, Helfinstein, Bar-Haim, Nelson, & Fox, 2009). The first is that from early on in development there are relations between attention bias toward threat and anxiety. The second position is that the association between attention bias toward threat and anxiety does not manifest until late in development. The third and final position is that attention biases are influenced through interactions between temperament and caregiver behavior. Discrepant findings make it unclear as to which position best accounts for the development of relations between anxiety and attention biases.

Research that finds relations between anxiety and attention bias early in development supports the first position. Martin and colleagues examined whether stroop effects on spider-related words would be found in spider phobic children at different ages (6-7 years, 9-10 years, and 12-23 years) (Martin, et al., 1992). They found a Stroop effect in the phobic children as young as 6 years old, thus supporting the first position. Also in support of this position, Roy and colleagues (Roy, et al., 2008) conducted a correlational design study in which they examined whether children with anxiety disorders have a greater attention bias toward threat than non-anxious children. Participants were made up of children and adolescents ages 7 to 18 years. The anxious group included 101 participants that met the diagnostic criteria for generalized anxiety disorder, social phobia, and/or separation anxiety disorder. The comparison group was comprised of 51 non-anxious youths. A dot-probe paradigm was used in order to assess attention bias toward threat (angry) faces and toward positive (happy) faces. Results indicate that anxious children demonstrated a greater attention bias toward threat than did the controls. In other words, the anxious participants displayed an overall faster reaction time to respond to the probe when it replaced the presentation of an angry face than when it replaced a neutral face. There were no group differences in biases toward happy faces. These findings suggest that pediatric anxiety disorders are associated with an attention bias toward threat. While this data are supportive of the first position raised in Pine et al., 2009, the participants are comprised of a broad age range and it is possible that the older children are in fact biasing the results.

Waters and colleagues used a narrower age range to examine the relations between childhood anxiety and attention biases (A. Waters, et al., 2000). While the dot-probe task is the most commonly used task to date with which to assess attentional biases, other tasks have been used to measure this phenomenon. Waters and colleagues used a startle eyeblink modification paradigm to measure attention bias in anxious children. The paradigm consisted of presenting participants with threat and neutral word pairs. A startle eliciting auditory stimulus (burst of white noise) was presented during the presentation of the words at lead intervals of 60, 120, 240 and 2000 ms and during inter-trial intervals. Participants included 16 children ranging from 9 to 13 years of age who were diagnosed with an anxiety disorder. Results indicate that these anxious children displayed startle latency shortening during threat words at the 60 ms lead interval. This is similar to startle findings in anxious adults (Aitken, Siddle, & Lipp, 1999). These results suggest that the startle eyeblink in anxious children is affected during threat words at an early lead interval and that these children display an attention bias toward threat. Anxiety may therefore influence the early processing of threat-related words in children. This study also supports the first position (D. Pine, et al., 2009) that early anxiety is related to attention bias toward threat.

Recently, Waters and colleagues examined attention bias in 8 to 12 year old children with anxiety disorders and non-anxious controls (A. Waters, et al., 2010). They found that children with more severe anxiety showed an attention bias toward threat compared to anxious children with milder anxiety and non-anxious controls, supporting the position that anxiety is related to biases toward threat early in development. While one can claim that anxious children have an attention bias toward threat, the development of this bias remains unknown. Did these anxious children always show a bias toward threat? Did it develop as their anxiety developed? More developmental work is needed to best examine the time course of attention biases.

Pine and colleagues' (2009) second position claims that anxious and non-anxious infants and young children display a bias toward threat and that later in development the bias is inhibited in non-anxious individuals but not in anxious individuals. By four months of age, infants are able to flexibly orient their attention to salient information in the environment (see Colombo, 2001 for review). LoBue and DeLoache (2010)examined whether 8- to 14-month-old infants display an attention bias toward threat-related stimuli. The study found that infants were quicker to orient toward snakes than flowers and towards angry faces than happy faces. These findings support the second position by providing evidence that typically developing infants more quickly detect threatening stimuli and have a general bias for threat detection.

Also in support of this position, Kindt and colleagues found a Stroop effect in 8 to 9 year old anxious and non-anxious children (Kindt, Brosschot, & Everaerd, 1997). Biases toward threat in anxious children did not differ from threat biases in non-anxious children. However, this position cannot be fully supported since there is also evidence that child anxiety is related to attention biases.

The third position discussed by Pine and colleagues (2009) claims that attention bias toward threat is expected to develop early on in specific populations who have predispositions to develop anxiety and are brought up in certain environments. Fox and colleagues suggest a model in which children with fearful temperament influence their caregiving environment and their environment influences their attentional biases (N. A. Fox, Hane, & Pine, 2007). Children with behaviorally inhibited temperaments react negatively to novelty and stress and when this temperament is combined with maternal insensitivity in which mothers highlight threat in the environment, it can lead to biases toward threat and in turn, anxious behavior.

Rubin and colleagues conducted a longitudinal study in which they examined how toddlers' temperament and parenting styles would influence social and behavioral problems in pre-school (Rubin, Burgess, & Hastings, 2002). Behavioral inhibition in toddlers was positively related to pre-school social reticence only with children whose mothers were over controlling and derisive. These results support the third position that parenting behavior acts as a moderator between behaviorally inhibited temperament and anxiety.

In partial support of the third position raised by Pine and colleagues (2009), there have been a growing number of studies that have found relations between social fearfulness and attention bias toward threat. Much of this initial empirical work was done using an emotional Stroop task. Schwartz, Snidman and Kagan (1996) found that adolescents who were classified as being behaviorally inhibited at two years of age showed greater emotional interference on a Stroop task than those who had been uninhibited. Perez-Edgar and Fox (2003) found that children who responded faster to emotion words on the Stroop were rated as significantly higher in social withdrawal, having more problems with anxiety and depression, higher in attention problems, more shy, and having overall greater social problems. These findings are similar to those done on temperament and the emotional Stroop in adults (Mauer & Borkenau, 2007), supporting the claim that temperamental factors play a role in emotional Stroop interference.

Lonigan and colleagues argue for a model of anxiety in which temperamental factors are mediated by attentional threat biases to increase risks of anxiety (Lonigan, Vasey, Phillips, & Hazen, 2004). Recent empirical evidence has provided support for this model. Pérez-Edgar et al. (2010) found that adolescents who displayed behavioral inhibition as young children showed greater attention bias toward threat, and this bias moderated the relation between early temperament and adolescent social withdrawal. Similarly, in a separate cohort, BI in toddlerhood predicted social withdrawal at five years of age (Perez-Edgar, et al., 2011). This association was moderated by attention bias toward threat, such that only inhibited children who showed an attention bias toward threat displayed social withdrawal at age five. These studies suggest that the coupling of BI and attention bias toward threat is a risk factor for the later development of social withdrawal. There is a need for a greater examination of the relations between attention bias toward threat in children and social fearfulness. In addition, there seems to be a gap in the literature on the relations between attention bias, age, and trait fearfulness.

All three positions raised by Pine and colleagues (2009) received partial support, however, more research is needed to best clarify the relations between development, attention bias toward threat and anxiety. It is important to determine the development of attention biases throughout typical development so that there can be a more concrete understanding of how biases are related to at-risk or anxious populations.

2.3 Adolescence

Adolescence is a transition period between childhood and adulthood that is marked by the onset of pubertal development. In males, puberty onset occurs with the release of testosterone from the testes, and in females the onset is marked by the release of estrogen and progesterone by the ovaries and uterus. The release of these gonadal hormones is responsible for the development of secondary sexual characteristics, such as breast development, pubic hair, and testicle growth (Marshall & Tanner, 1969, 1970). Adolescence is associated with extensive psychosocial and physiological changes that lead to both developmental advancements and sensitivities (Crone, 2009). For example, this time period is associated with increases in abstract reasoning, selective attention, and goal-directed behavior, but it is also related to increased risk-taking and social evaluation (Crone, 2009) (Yurgelun-Todd, 2007).

In addition to an array of cognitive improvements in adolescence, there are also changes seen in emotional development and the impact of social context. Common to adolescence is a growing independence from parents and a shift in the importance and influence of peers (i.e. Hartup & Stevens, 1997). Behaviors and decision-making during adolescence are greatly impacted by peers and adolescents show an increased sensitivity to the opinions of others (Gardner & Steinberg, 2005; Steinberg, 2005). Rejection sensitivity is particularly salient during this developmental period. A recent longitudinal study found that rejection sensitivity in adolescence was related to anxiety and depressive symptoms (Marston, Hare, & Allen, 2010). Social sensitivity is one possible risk factor that may help explain individual differences in threat bias acquisition.

Along with changes in the influence of social context on behavior, come changes in the discrimination between and processing of affective faces. Thomas and colleagues used a morphed emotional faces task to examine emotional discrimination in late childhood, adolescence and adulthood (Thomas, De Bellis, Graham, & LaBar, 2007). Adults were able to better discriminate subtle emotional changes in the neutral-to-fear, neutral-to-anger, and fear-to-anger morph conditions than were children and adolescents. There was a linear increase in sensitivity to fear emotions across the three age groups, whereas anger sensitivity showed a quadratic trend in which there was a large increase between adolescents and adults (Thomas, et al., 2007). McClure (2000) conducted a meta-analysis to examine sex differences in facial expression processing in infants, children, and adolescents and found a female advantage over all developmental periods. Not only is social context particularly salient in adolescence but the ability to read social and emotional cues increases during this developmental period (Herba & Phillips, 2004).

The examination of threat bias acquisition during ages surrounding adolescence seems of particular importance since this developmental period is considered a time of heightened vulnerability for the onset and intensification of anxiety problems, with more robust relations in females than males. In females, positive relations have been found between pubertal status and anxiety (Hayward et al., 1992; Huerta & Brizuela-Gamino, 2002; Patton et al., 1996). A recent review provided evidence to support a positive relation between anxiety and puberty in females even when controlling for age, but the findings among males have been mixed (Reardon, et al., 2009).

Perhaps more compelling, are findings that suggest that puberty accentuates pre-existing vulnerabilities in children. This accentuation hypothesis was first proposed by Caspi and Mofitt (1991) who found that early menarche related to magnified behavioral problems in girls who were predisposed to behavioral problems in early childhood. More recently, Leen-Feldner and colleagues (2006; 2007) found that the interaction between pubertal status and anxiety sensitivity predicted anxious responding to a hyperventilation task. The ease at which youth acquire an attention bias toward threat may reflect one type of anxiety vulnerability that may be exacerbated by later pubertal status.

Moreover, there may be certain populations in which attention bias toward threat is more likely to lead to anxiety problems. One such “risky” population is of children with trait fearfulness. Longitudinal research has shown that biases early in life may moderate risk for later anxiety in behaviorally inhibited children (Perez-Edgar, et al., 2011). Youth are heavily influenced by their peers and the degree to which adolescents worry about fitting in and being socially rejected is another potential vulnerability that is particularly heightened in adolescence and can lead to distress. Experimental work examining how the modulation of attention bias toward threat relates to temperament and social sensitivity may help characterize children at risk for later anxiety.

2.4 Attention Bias Modification

Attention Training of Non-Anxious Adults toward Threat

While previous research has found an association between attention bias toward threat and anxiety, it is important to determine causality in order to best understand their relations and to inform novel treatments. The link between attention bias toward threat and anxiety has been demonstrated in the laboratory through experimental manipulation of attention biases. In addition, some studies have examined how attention bias manipulation affects stress reactivity.

MacLeod and colleagues used a modified dot-probe task in order to train individuals’ attention toward threat (MacLeod, et al., 2002). Participants scoring within the middle third of scores on the STAI-T were randomly assigned to either an attend neutral or an attend negative group. All participants completed a dot-probe session of 672 trials. There were 576 training trials and 96 testing trials presented randomly throughout the task. The modified dot-probe used for training consisted of simultaneously presenting a neutral and a threat-related word. Following this word pair presentation, a probe appeared on the screen in the location of one of the previous words. Participants made a behavioral response to the location of the probe. The training for those in the attend negative group consisted of 576 dot-probe trials in which the probe was always located behind a negatively valenced word. The training for those in the attend neutral group consisted of 576 dot-probe trials in which the probe always appeared behind the neutral word. Both training groups also completed 96 trials in which the probe appeared an equal number of times behind each affective stimulus.

Stress reactivity was also examined in this study (MacLeod, et al., 2002). Following the dot-probe task, participants completed a set of mood scales in which they rated their current anxiety and depression levels. Participants then completed an anagram task that was manipulated to induce stress. Lastly, participants filled out another set of depression and anxiety mood scales.

Results indicated that the training procedure was successful in altering attention allocation. Those in the attend negative group showed faster response times to the cue when it was located behind a threat-related word, whereas those in the attend neutral condition were faster to respond to the cue located behind the neutral word. Although there were no significant mood scale differences before the stress task, there were group differences in mood scale ratings following the stressor. Individuals trained to attend to threat-related stimuli responded more negatively to a stressful event after the training than those who were trained to attend neutral stimuli. This study was one of the first conducted in which attention was manipulated in order to examine effects on stress vulnerability.

O'Toole and Dennis (2012) used a modified dot-probe task using happy and angry faces to train non-anxious adults toward or away from threat. In addition, event-related potentials (ERPs) during the pre- and post-training assessments were examined. Overall the groups did not differ on threat bias scores after training. Analyses were then done comparing participants in the train toward threat group who had an initial bias away from threat to participants in the train away from threat group who had an initial bias toward threat. Results on this subset of participants revealed post training group differences in bias scores. These findings must be interpreted cautiously as the results may just be due to regression to the mean.

One major concern with the studies conducted by Macleod and colleagues (2002) and O'Toole and Dennis (2012) is that no clear interpretation can be made as to what is driving the group differences. In the MacLeod study, participants trained to attend toward threat are compared to participants trained to attend toward neutral. The outcome differences in stress vulnerability between the groups may be driven by the training to threat or the training away from threat or a combination of the two. There is a similar problem when drawing conclusions from the bias findings in the study conducted by O'Toole and Dennis since participants trained toward threat are compared to participants trained toward happy. A control group in which there is no direct training could be used in order to more clearly decipher training effects.

Suway and colleagues used a paradigm in which participants were trained toward threat or were in a non-training placebo group (Suway et al., 2012). For trials in the placebo group, the probe appeared behind the threat and neutral face with equal probability. In addition, to collecting behavioral data they included the collection of electroencephalography (EEG) in order to examine even-related potentials (ERPs). Results indicated that not only did attention training influence biases toward threat and stress reactivity, but also that cortical brain activity was influenced. Those trained toward threat showed enhanced P2 ERP amplitudes when viewing faces in comparison to the non-trained controls. The P2 amplitude has been positively associated with threat processing. The use of training and non-training groups makes it easier to draw conclusions that training toward threat drove the findings. In addition, the study suggests that not only does attention training influence behavior but also underlying psychophysiological processes.

Attention Training of Non-Anxious Children toward Threat

Eldar and colleagues conducted the first study to use a modified dot-probe task to train attention in children (Eldar, et al., 2008). Non-anxious 7-12 year old children were either trained toward threat or neutral stimuli. The dot-probe task used angry and neutral faces as opposed to words so that differences in reading ability would not affect the training. Overall, there are no differences in biases between dot-probe paradigms using picture versus word stimuli (Bar-Haim et al., 2007). The study was conducted using a modified dot-probe paradigm over two sessions on two separate days. Results indicate that children trained to attend to angry faces showed a significant increase in attention bias toward threat. Children trained to attend to the neutral faces did not show a significant change in attention bias. Although both groups showed increased depression ratings between pre-stress to post-stress assessments, only the group trained to threat showed increased anxiety ratings after the stress induction, suggesting that the training affects anxiety. In addition, children trained to attend to angry faces displayed more anxious behaviors during the stress task than did those trained to attend to neutral faces. This is the first study to show that it is possible to train attention bias toward threat in children.

Attention bias modification can be used to induce a threat bias in attention. These findings have important theoretical and practical implications. First, attention bias can be manipulated through training. Second, this bias influences stress vulnerability. Lastly, ABM can leads to psychophysiological changes of the way threat is perceived. These studies raise the question as to whether similar procedures can be used to decrease attention bias toward threat and in turn decrease emotional vulnerability to stress.

Attention Training Away from Threat

Recently, cognitive bias modification procedures have been used to examine whether reducing threat biases in anxious populations can decrease anxiety and emotional vulnerability. In attention training, this is usually done by directing subjects' attention toward neutral stimuli and away from threatening stimuli using a modified dot-probe paradigm. This training away from threat has been done with both clinically anxious populations and participants with high trait anxiety (e.g. Amir, Burns, & Bomyea, 2009; Eldar & Bar-Haim, 2010; Schmidt, Richey, Buckner, & Timpano, 2009). The use of cognitive bias modification to reduce anxiety symptoms in clinical populations has received much attention due to its potential use as a treatment. A recent meta-analysis revealed a significant benefit of the use of attention bias modification on anxiety measures (Hakamata et al., 2010).

Bar-Haim, Morag and Glickman (2011) published the first randomized controlled attention bias modification study in anxious children. They used a modified Posner cueing task in which a cue appeared in one of two locations on a computer screen and was followed by a target. The target appeared at the cued location for a majority of trials (valid cue) and at the alternative location for a minority of trials (invalid cue). Bar-Haim and colleagues (2011) used angry and neutral faces as affective cues. The use of this emotional attention spatial cueing task allows the examination of attention disengagement from threat. High anxious 10-year-olds were randomly assigned to a training away from threat condition or a placebo control condition. In the training condition, threat-faces never cued the target's locations. Training took place over two different sessions and pre- and post-training stress induction tasks were completed.

Bar-Haim and colleagues (2011) found that training anxious children away from threat facilitated attention disengagement from threat. In addition, children in the training group reported less state anxiety after the stressor in comparison to controls. This study is the first to show that attention bias modification tasks can be used with children to reduce biases toward threat and stress vulnerability. Results support the possibility that attention training can be used to treat anxious children.

While the prospect of reducing anxiety and emotional vulnerability through training is exciting both theoretically and practically, and there have been some notable successes, many methodological issues must still be addressed. Specifically, while biases in attention have been well studied in adult populations, we still do not know how these biases differ across development. Studies that have been done with children use large age ranges, so we are not getting the full developmental picture. A longitudinal study on bias assessment or cross-sectional work may be helpful in exploring individual differences in how biases are acquired. In addition, there are very few training studies that have been done with children in order to assess how the manipulation of attention bias can alter behavior. It is difficult to fully understand the relations between attention bias, stress reactivity, and anxiety if we do not know how training effects differ across age. Before spending resources on studies attempting to train anxious children away from threat, it is important to first understand how experimental manipulation of attention bias toward threat affects behavior across development. Once this is clearly examined, more effective anxiety treatments for children using ABM can be developed.

2.5 Summary

Research has shown that attention bias can be experimentally manipulated through ABM and successful manipulation of threat bias is related to changes in stress reactivity. While attention bias toward threat has been examined in children, no study to date has cross-sectionally examined the effects of age on threat-related ABM. Since adolescence is a time of high risk for those who already show vulnerabilities, the current study will focus on ages surrounding this period, specifically, early childhood, middle childhood, and young adulthood. The current study examined age differences in the acquisition of an attention bias toward threat and how this relates to stress reactivity. In addition, we examined the relations between pubertal development and both bias acquisition and stress reactivity. Lastly, the effects of trait fearfulness, anxiety and social sensitivity were examined as possible mechanisms that may explain age-related differences in threat bias acquisition.

Chapter 3. The Current Study

3.1 Statement of the Problem

The literature suggests that attention bias toward threat is related to the development and maintenance of anxiety. Attention toward threat has been studied in relation to personality traits and stress reactivity. Additionally, studies suggest that this bias can be induced in non-anxious individuals through use of training paradigms. Few studies have examined ABM across development and to date no study has examined if threat bias acquisition varies across these developmental periods.

In adults, the ease at which a bias toward threat is acquired is positively related to the degree of anxiety experienced in response to a mild stressor (Clarke, et al., 2008). In other words, individual differences in threat bias acquisition during an attention training task predict stress reactivity. The readiness to acquire an attention bias toward threat can potentially be used to help identify individuals at risk for anxiety. This relation has not been studied developmentally so it remains unclear as to whether threat bias acquisition differs across age and whether the relations between bias acquisition and stress reactivity are the same in children as they are in adults. The current study examined possible mechanisms that may relate to the ease of bias acquisition. Specifically, the study examined pubertal stage, trait fearfulness and social sensitivity.

3.2 Overview of the proposed study

The current study examined whether there are age differences in the acquisition of an attention bias toward threat and whether there are age differences in stress reactivity as a function of training. In addition, we examined whether pubertal development related to bias acquisition and stress reactivity, and whether these relations existed independent of age. Lastly, we examined whether trait fearfulness and social sensitivity correlated with threat bias acquisition within each age group. By improving our understanding of threat bias acquisition across development, we may be able to better identify those at risk for anxiety.

For the proposed study, three age groups were recruited to participate: children approximately 8 years of age and 12 years of age, as well as young adult group consisting of University undergraduates 18 years of age. Only female participants were recruited due to gender differences in pubertal timing (Sun et al., 2002), gender differences in the relations between puberty and anxiety (Reardon, et al., 2009), and because females have a greater stress-reactivity profile (De Rivera, De las Cuevas, Monterrey, Rodriguez-Pulido, & Gracia, 1993). Participants completed the Screen for Child Anxiety Related Disorders (SCARED; Birmaher et al., 1997) and only those with scores ≤ 25 completed training.

Participants were asked to complete a lab visit that consisted of physical development, temperament, social sensitivity and anxiety questionnaires, completion of a modified dot-probe task, and participation in a mild stress task. Participants underwent attention training by means of a modified dot-probe task consisting of angry-congruent trials. Age differences in bias acquisition and stress reactivity were examined. In addition the relations between puberty and both bias change and stress reactivity were examined. We also assessed how bias acquisition related to trait fearfulness, pubertal stage, and social sensitivity within each age group.

Chapter 4. Methods

4.1 Participants

Thirty-seven eight-year-old female children (M_{age}= 102.34 months, *SD*= 4.19, range = 96.0–109.9) and thirty-eight twelve-year-old female children (M_{age}= 147.33 months, *SD*= 4.71, range = 138.4–157.1) were recruited through commercially available mailing lists and flyers. Thirty-one female young adults (M_{age}= 230.19. months, *SD*= 5.15, range = 222.6–239.8) were recruited for the third developmental group through university operated recruitment websites. Of these 106 participants, seventy-six of them had SCARED scores ≤ 25 so were administered the attention training task and stressor. Data analyses were conducted with these seventy-six participants (N_{8years} = 24; $N_{12years}$ = 27; $N_{18years}$ = 25). Ethnicity and race were self-reported as: 51% Caucasian, 11% African American, 11% other, 5% Hispanic, 4% Asian, and 18% unreported.

4.2 Procedures

Table 1 describes the sequence of events that was used in the study. After obtaining consent, participants were administered a set of questionnaires (see Table 2) and then mood scales (mood scale set 1). Participants were then administered the dot-probe paradigm, consisting of the pre-training bias assessment trials, training trials, and post-training bias assessment trials. This was followed by a set of mood scales (mood scale set 2). Participants were then administered the speech stress task, filling out the moods scales (mood scale set 3) after speech preparation and then after giving the speech (mood scale set 4). At the end of the session, participants were debriefed.

Table 1. Procedures

Outline of Procedures
Questionnaires
Anxiety- STAI-C/STAI-Y
Trait Fearfulness- EATQ-R, ATQ
Pubertal Stage – PDS
Social Sensitivity – RSQ, NBS
Mood Scales (set 1)
Dot-probe Task (pre, training, post)
Mood Scales (set 2)
Speech Task Preparation
Mood Scales (set 3)
Speech Task
Mood Scales (set 4)

Table 2. Group Means (SDs) for Questionnaires

	SCARED	**STAI-Y Trait**	**STAI-C Trait**	**STAI-Y State**	**STAI-C State**	**PDS**	**NBS**	**ATQ-Fear**	**EATQ-Fear**
Age 8	14.38 (*7.39*)		32.10 (*6.46*)		27.71 (*4.44*)	1.38 (*.39*)	35.81 (*4.40*)		2.72 (*.87*)
Age 12	16.52 (*6.97*)		29.11 (*4.37*)		26.70 (*3.57)*	2.68 (*.72*)	32.52 (*5.13*)		2.54 (*.78*)
Age 18	18.52 (*5.12*)	35.40 (*5.92*)		32.44 (*7.82*)		3.90 (*.14*)	35.56 (*5.86*)	3.76 (*.72*)	

Our dot-probe cleaning procedures were the same as used in the standard Tel-Aviv University/National Institute of Mental Health ABM toolkit. Dot-probe trials with incorrect responses and reaction times (RT) less than 200 ms after target presentation were excluded from further analyses. In addition, RTs above and below two standard deviations of the mean RT for each condition within each block for each subject was excluded from the mean reaction time calculations. To calculate bias scores, mean RTs on congruent trials were subtracted from mean RTs of incongruent trials, such that higher scores on the bias index reflect an attention bias toward threat and negative scores reflect an attention bias away from threat and toward neutral. Difference scores between pre-training and post-training bias scores reflect bias change. Participants' accuracy and RT bias for pre- and post-training assessments were examined for significant outliers. One participant in the youngest group was removed from analyses due to extremely low accuracy rate. As well, three outliers in the 8-year old group were removed from analyses due to bias scores ranging outside 2.5 SD of the mean. Therefore, the final sample included 73 participants.

4.3 Measures

Dot-Probe Task: Stimuli

All stimuli were presented on a white rectangle that measures 94 mm tall by 58 mm wide. This rectangle was overlaid on a black background. A fixation consisting of a black cross in the center of the white rectangle was presented on the screen before the presentation of the faces. The face stimuli consisted of 20 individuals (10 female) all of which were taken from the NimStim Face Stimulus Set (Tottenham et al., 2009), except one set of female faces which was taken from the Matsumoto and Ekman set (Matsumoto & Ekman, 1989). Photographs of neutral and angry facial expression were used for each individual. Each face pair display consisted of angry-neutral or neutral-neutral faces of the same individual presented vertically. Each photograph was 34 mm tall by 45 mm wide, and the two facial expressions were presented with 14 mm of space between them. The top photograph was positioned approximately 20 mm from the top of the monitor. The target-probe consisted of an arrow that was oriented either left or right ("<" or ">")

and was presented in the location previously occupied by one of the faces, with a small random jitter around the center of the face. See Figure 1.

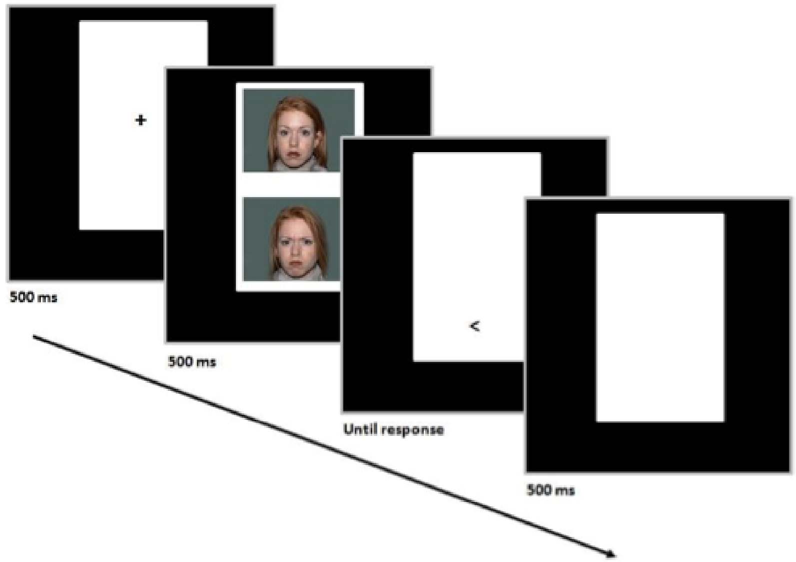

Figure 1. Dot-Probe Task

Dot-Probe Task: Procedures

The dot-probe task and procedures were modified from a standard ABM protocol toolkit created by Tel-Aviv University in collaboration with the National Institute of Mental Health. During the dot-probe task, subjects were asked to respond by a key-press to indicate whether the target is pointing left or right ("<" or ">"). This target appeared in one of two locations, either a top or bottom of the screen position and remained on the screen until a button press was made. Immediately prior to target presentation, visual cues in the form of pictures appeared in each location for 500 ms. Picture cues were presented as either neutral or angry faces. Each trial consisted of a "cue" slide consisting of face pairs, followed by a "target" slide. Face pairs were presented in one of two combinations: neutral/neutral and angry/neutral. The location of the emotional face and the target was counter-balanced across the experiment.

A pre- and post-training bias assessment of 120 trials was administered. For the angry/neutral trials of the bias assessment task, the probe appeared behind the angry and the neutral face with equal probability (50% congruent angry, 50% incongruent neutral). If participant accuracy was less than 70% on the first 10 trials, then the program displayed a warning and will stop running. This allowed the experimenter to re-brief the participant and re-administer the task. By comparing reaction time data across the two types of picture cues, a measure of vigilance or attention bias was generated.

During training, participants completed 320 dot-probe discrimination trials of angry/neutral and neutral/neutral face pairs over two blocks. Each block consisted of 160 trials. Seventy-five percent of these trials (120 trials) consisted of angry/neutral trials. The remaining 25% (40 trials) consisted of neutral/neutral trials. For training, the target appeared at the angry face location for all the angry-neutral trials. There was a brief break every 40 trials. If accuracy was below 70%, then a warning appeared during the break so the experimenter could remind the participant about the importance of accuracy on the task. Participants were given another short break after the first block of training and then the second and final training block begun.

To calculate pre-training and post-training bias scores, mean RTs on congruent trials were subtracted from mean RTs of incongruent trials, such that higher scores on the bias index reflect an attention bias toward threat and negative scores reflect an attention bias away from threat and toward neutral. To calculate bias change scores, pre-training bias assessment scores were subtracted from post-training bias assessment scores, such that higher change scores reflect a greater threat bias acquisition.

Screening

The SCARED (Birmaher, et al., 1997) self-report questionnaire consists of 41 items designed to assess anxiety symptoms in children up to 18 years of age. Previous research has used a cutoff score of 25 to indicate a possible anxiety disorder (e.g., Birmaher et al., 1999). The current study used this measure as a screening tool to ensure that anxious participants were not included in training.

Pubertal Development

The Physical Development Scale (PDS) (Petersen, Crockett, Richards, & Boxer, 1988) includes a series of gender-specific questions about growth spurt, body hair growth, skin change, breast development and the age of onset of menarche. The scale allows for a pubertal development score as well as the categorization of participants into one of the 5 Tanner stages of puberty (stage 1: pre-pubertal, stage 2: beginning pubertal, stage 3: mid-pubertal, stage 4: advanced pubertal, stage 5: post-pubertal). Since some of the younger children did not understand the content of the PDS, parents were asked to assist when appropriate. During consent, parents were asked whether they felt comfortable having their child try to fill out the PDS or whether they preferred to complete the questionnaire themselves. In instances when children in the youngest group filled out the form on their own, a parent would go over the responses to confirm that there wasn't any confusion on an item.

Trait Fearfulness

The *Early Adolescent Temperament Questionnaire Revised* (EATQ-R) is a 65-item self-report assessment to examine ten different dimensions of temperament in adolescents aged 9 to 15 years (Simonds, Kieras, Rueda, & Rothbart, 2007). This questionnaire was used with the 8- and 12-year old groups to assess trait fearfulness.

The *Adult Temperament Questionnaire* (ATQ) is a 77-item self-report assessment to examine different dimensions of adult temperament (Ellis & Rothbart, 2001). This questionnaire was used with the young adult group to assess trait fearfulness.

Proportion scores were made in order to put the EATQ and ATQ measures on the same scale. Proportion scores were calculated by dividing each fear score by the maximum possible score on the scale. For the EATQ fear subscale, scores were divided by 5 (the maximum possible score). For the ATQ fear subscale, scores were divided by 7 (the maximum possible score). These proportion scores could then be compared because they were on the same scale and measured the same construct.

Trait Anxiety

The *State-Trait Anxiety Inventory for Children* (STAI-C) (Evans & Rothbart, 2007) is a 40-item questionnaire designed to measure levels of state anxiety and trait anxiety in children between the ages of 8 and 14 years. This measure was used with the 8- and 12-year-old groups to examine anxiety. The STAI-C has been successfully used in previous research to screen levels of anxiety and detect changes in anxiety over time (Spielberger, Edwards, Lushene, Montuori, & Platzek, 1973) and can be administered in paper format or verbally to children (Bar-Haim, et al., 2011).

The *State-Trait Anxiety Inventory* (STAI-Y) (Spielberger, et al., 1973) is a 40-item questionnaire designed to measure levels of state anxiety and trait anxiety in participants 15-years of age and older. This measure was used with the18-year old group to examine anxiety.

Proportion scores were made in order to put the STAI-Y and STAI-C measures on the same scale. Proportion scores were calculated by dividing each score by the maximum possible score. For the STAI-Y, scores were divided by 80 (the maximum possible score). For the STAI-C, scores were divided by 60 (the maximum possible score). These proportion scores could then be compared because they were on the same scale and measured the same construct.

Social Sensitivity

The *Rejection Sensitivity Questionnaire* (RSQ) consists of 18 hypothetical situations where rejection by another person is possible (Downey & Feldman, 1996). Participants were asked to rate their level of concern about the outcome of the situation as well as the likelihood of the situation having a positive outcome. For the current study, we focused on questions that assessed sensitivity to peer rejection.

The *Need to Belong Scale (*NBS) is a 10 item measure that asks participants to complete a 5-point Likert scale on whether they agree or disagree with statements related to one's need of social acceptance (Leary, Kelly, Cottrell, & Schreindorfer, 2007).

In order to create a general measure of social sensitivity, the RSQ peer rejection score and NBS score were standardized and summed. This measure was confirmed via factor analysis (Eigenvalue= 1.43, $M_{loading}$ =0.76).

Interrcorrelations between Variables

As seen in Table 3, the three anxiety subtype measures were significantly correlated. The pubertal development measure was correlated with the SCARED but not with the index of trait anxiety/fear or the social sensitivity composite.

Table 3: Correlation Matrix of Trait and Puberty Measures

	Trait Anxiety/Fear Index	Social Sensitivity Composite	PDS
SCARED	.569**	.423**	.246*
Trait Anxiety/Fear Index		.301**	-.214
Social Sensitivity Composite			.120

* *p* <.05
** *p* < .01

Analogue Mood Scales

The analogue scales were presented to the participants throughout the study to measure changes in self-report ratings of anger, anxiety, happiness and depression. Each analogue mood scale consisted of a 15 cm horizontal line divided into 30 equal sized partitions. Each scale had terminal labels, “very much” and “not at all”. Participants were asked to rate their current mood on these scales by marking where on the axis they felt best described their mood. These scales have been used successfully in previous research (i.e. MacLeod, et al., 2002).

Speech Stress Task

The speech version of the Trier Social Stress task was used to examine reactivity to social stress. Participants were told that they were going to give a 5-minute speech in front of researchers about why they should be elected for class president. They received a pen and paper and had 2 minutes alone to prepare their speech. Two research assistants in lab coats then sat down with clipboards and a camera is brought into the room and turned on. After the 5-minute timer begins, participants were asked to begin their speech. Prompts were provided if a participant finished before the allotted time. The analogue mood scales were given after the task preparation and the speech presentation in order to examine stress reactivity.

4.4 Data Analyses Plan

First, we examined the effectiveness of ABM between age groups.   We hypothesized that 18-year-old subjects would show a greater increase in bias change compared to the 8 and 12-year-old groups. To test this hypothesis, we conducted a univariate ANOVA with group as the independent variable (age 8, age 12, age 18) and bias change as the dependent variable. Follow-up tests were conducted to evaluate pairwise differences among the means.

Second, we examined if there were age differences in the relations between change in threat bias, as a function of training, and stress reactivity. Stress reactivity scores were created by calculating difference scores between the mood ratings given before and after the speech task, using the anxiety and depression scale types (stress reactivity = mood scale after speech – mood scale before speech). We hypothesized that bias change would positively correlate with stress reactivity, and that these relations would be stronger with age. Pearson's correlations were conducted within each age group to examine the relations between bias change and stress reactivity. Fisher's z transformations were used to examine if the correlations differed between age groups.

Third, we examined if pubertal development, irrespective of age, was related to bias change and stress reactivity. Three equally sized groups were created from the pubertal development scores (early, mid, and advanced). We conducted a univariate

ANCOVA with pubertal group as the independent variable (early, mid, advanced), age in months as the covariate, and bias change as the dependent variable. When appropriate, follow-up tests were conducted to evaluate pairwise differences among the means. ANCOVAs were also conducted with our stress reactivity measures as dependent variables. We hypothesized that the more advanced pubertal group would show greater bias change and greater stress reactivity than the less developed groups.

We also examined the overall relations between pubertal development scores and our dependent variables. Correlational analyses were conducted between pubertal scores and bias change and between pubertal scores and stress reactivity. We hypothesized that pubertal development scores would positively correlate with bias change and with stress reactivity. Partial correlations were also conducted to examine these relations while controlling for age.

Next, we looked within our age group with the greatest pubertal variation, the 12-year olds. We examined possible differences in the relations between stress reactivity and bias change in the early pubertal versus the advanced pubertal 12-year olds. A median split on pubertal score was run within the 12-year old group, and correlations between stress reactivity and bias change were conducted. Fisher's z transformations were used to examine if the correlations differed between the early and late pubertal 12-year olds.

Lastly, we examined if our trait measures were related to bias change. Trait anxiety and trait fearfulness measured similar constructs and were significantly correlated ($r = .44$), so the standardized anxiety and fearfulness scores were summed to create an index of trait anxiety/fearfulness. Our social sensitivity measure did not significantly correlate with our anxiety and fear measures and was examined separately. We hypothesized that greater trait anxiety/fearfulness and social sensitivity would relate to greater bias change and that the strength of these relations would be strongest in the older groups. We conducted correlational analyses between our index of trait anxiety/fearfulness and the social sensitivity measures and bias change. Fisher's z transformations were used to examine if the correlations differed between age groups.

4.5 Preliminary Analyses

Bias in High SCARED (Untrained) Participants

Before examining our primary aims with the participants who underwent the attention training procedure, bias scores in the participants who were not trained due to high SCARED scores were analyzed. Of the 30 untrained participants, one participant did not have bias data due to a data collection error. As well there were two outliers removed from analyses due to bias scores ranging outside 2.5 SD of the mean. Thus, we examined bias scores for a sample of 27 untrained participants, $M_{bias} = 0.70$, SD_{bias} = 37.75. The bias scores of these high SCARED participants did not differ from the bias scores of those with low SCARED scores, $M_{bias} = 0.10$, SD_{bias} = 24.54; $t(97) = .09$, $p = .93$.

Training Effects on RT and Attention Bias

Before examining the stated age-related hypotheses, overall learning and mood were examined. Dot-probe learning was assessed through plotting mean RTs for each type of affective face pair (see Figure 2). Participants displayed a decrease in mean RT from the start to end of the task. Results indicated a significant main effect of time on RT, $F(2.10, 145.08) = 17.15$, $p < .001$. As well, there was a significant time x affect pair interaction, $F(2.50, 173.42) = 4.03$, $p = .01$. Lastly, there was a trend time x affect pair x age group, $F(5, 172.42) = 2.19$, $p = .06$. Follow-up analyses suggest that for the Neutral/Threat pairs, RTs became faster from pre to training 1, $p < .001$. For Neutral/Neutral pairs, RTs became faster pre-training to training one, and from training one to training two, $ps < .01$.

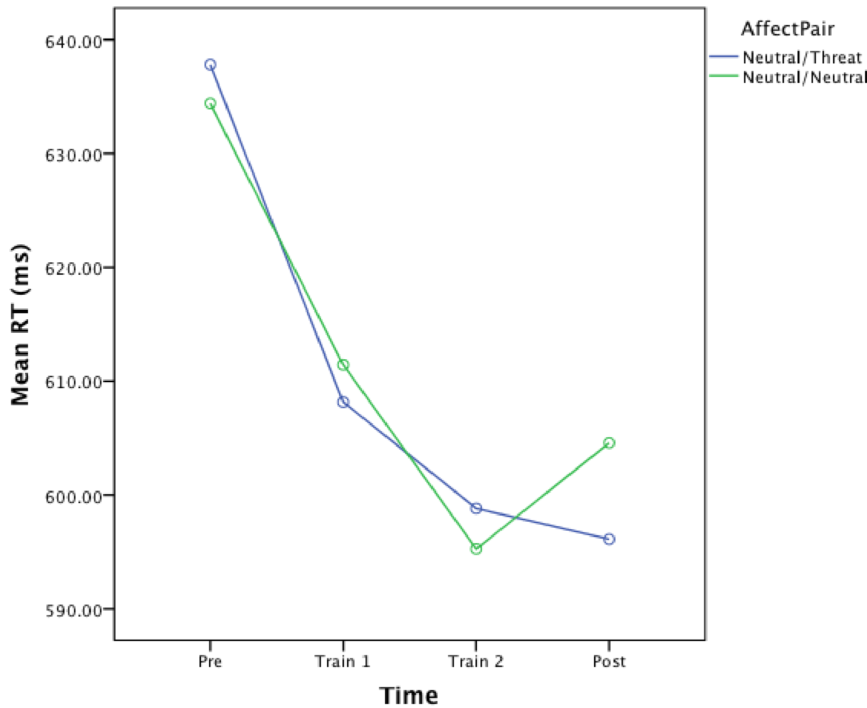

Figure 2. Mean RT Over Time for Each Affective pair type

Means for bias assessments and bias change can be found in Table 4. Results indicated overall accuracy rates were high ($M_{pre\text{-}training} = 97.28\%$, SD = 3.43%; $M_{post\text{-}training} = 96.84\%$, SD = 3.17%). A paired-samples t test indicated that there was no overall difference in pre-training bias and post-training bias, $t(71) = -.14$, $p = .89$.

Table 4. Group Means (*SDs*) for Bias Assessments and Change

	Pre-Train Bias Assessment	Post-Train Bias Assessment	Bias Change (Post-Pre)
Age 8	-2.96 (*28.88*)	16.49 (*43.67*)	19.46 (*50.97*)
Age 12	-3.99 (*24.63*)	-7.87 (*29.58*)	-3.89 (*39.94*)
Age 18	7.39 (*19.09*)	-3.73 (*23.88*)	-10.51 (*34.82*)

Mood Assessments

See Table 5 for means and standard deviations for each mood assessment. A repeated measures ANOVA was conducted with Time (time 1, time 2, time 3, time 4) and Scale Type (happy, angry, depressed, anxious) as within subjects factors. The results indicated a significant time effect, $F(2.07, 145.06) = 9.33$, $p < .001$ as well as a significant effect of scale type, $F(1.41, 98.79) = 215.23$, $p < .001$. In addition, there was a significant time x scale type interaction, $F(4, 280.35) = 15.12$, $p < .01$.

Table 5. Means (SDs) for Mood Scales

	Before Dot-Probe			After Dot-Probe			After Speech Preparation			After Speech		
	Age 8	*Age 12*	*Age 18*	*Age 8*	*Age 12*	*Age 18*	*Age 8*	*Age 12*	*Age 18*	*Age 8*	*Age 12*	*Age 18*
Nervous	4.03 (*5.04*)	4.89 (*6.96*)	7.18 (*7.42*)	4.38 (*5.82*)	2.78 (*5.25*)	4.98 (*5.27*)	7.52 (*8.87*)	10.30 (*9.86*)	13.18 (*7.18*)	7.24 (*9.95*)	7.48 (*7.90*)	9.38 (*8.20*)
Angry	1.48 (*2.02*)	1.48 (*2.93*)	2.90 (*4.55*)	3.45 (*6.84*)	2.33 (*3.96*)	4.50 (*5.08*)	3.14 (*5.84*)	4.65 (*7.73*)	4.54 (*4.68*)	4.19 (*6.22*)	6.04 (*9.05*)	6.10 (*6.34*)
Sad	1.48 (*2.59*)	1.22 (*2.24*)	3.58 (*3.81*)	1.95 (*3.69*)	.96 (*1.58*)	3.22 (*4.57*)	3.62 (*5.72*)	3.26 (*6.08*)	3.06 (*4.08*)	3.33 (*5.90*)	3.89 (*7.57*)	4.78 (*5.09*)
Happy	26.43 (*5.66*)	26.07 (*3.78*)	22.26 (*4.96*)	24.52 (*7.92*)	25.30 (*5.25*)	19.66 (*6.25*)	21.71 (*10.93*)	21.89 (*8.75*)	18.30 (*6.07*)	22.19 (*10.35*)	22.30 (*8.91*)	18.58 (*6.47*)

Follow up analyses on the happy mood scales also revealed a decrease in participants' ratings of happy mood after attention training (time 1 to time 2), $p < .001$. Lastly, there was a significant decrease in reported happiness from before the speech instructions to after the speech preparation (time 2 to time 3), $p = .01$.

Follow up analyses on the anger mood scales revealed a significant increase in reported anger from before the dot-probe to after attention training (time 1 to time 2), $p = .01$. There was also a significant increase in reported anger from after the speech preparation to after the speech was given (time 3 to time 4), $p = .04$.

Follow up analyses on the depression mood scales revealed a significant increase in self-reported sadness from before the speech instructions to after the speech preparation (time 2 to time 3), $p = .02$.

Follow up analyses on the anxiety mood scales revealed a significant decrease in reported anxiety after attention training (time 1 to time 2), $p = .01$. There was a significant increase in self-reported anxiety from before the speech instructions to after the speech preparation (time 2 to time 3), $p < .001$. Lastly, there was a significant decrease in anxiety from after the speech preparation to after the speech was given (time 3 to time 4), $p = .001$.

We then ran analyses to assess whether there were overall group differences in stress reactivity. Results indicated that the groups did not differ in reported anxiety levels of stress reactivity, $F(2,70) = 2.04$, $p = .14$. As well, the age groups did not differ in reported depression levels of stress reactivity, $F(2,70) = 1.06$, $p = .35$.

Chapter 5. Results

5.1 Bias Change and Age

The age groups did not significantly differ in attention bias at pre-training, *p*'s > .05. A one-way analysis of variance compared the mean bias change of the 8 year olds (*M* = 19.45, *SD* = 50.97, 12 year olds (*M* = -3.89, *SD* = 39.94) and 18 year olds (*M* = -10.51, *SD* = 34.8) (see Figure 3). Using an alpha level of 0.05, this test was found to be statistically significant, *F*(2,69) = 3.12, *p* = .05. Post-hoc Tukey HSD test indicated that the mean bias change for the 8-year-old group was significantly different than the mean bias change for the 18-year-old group. The mean bias change for the 12-year-old group did not differ significantly from the mean of either of the other two groups.

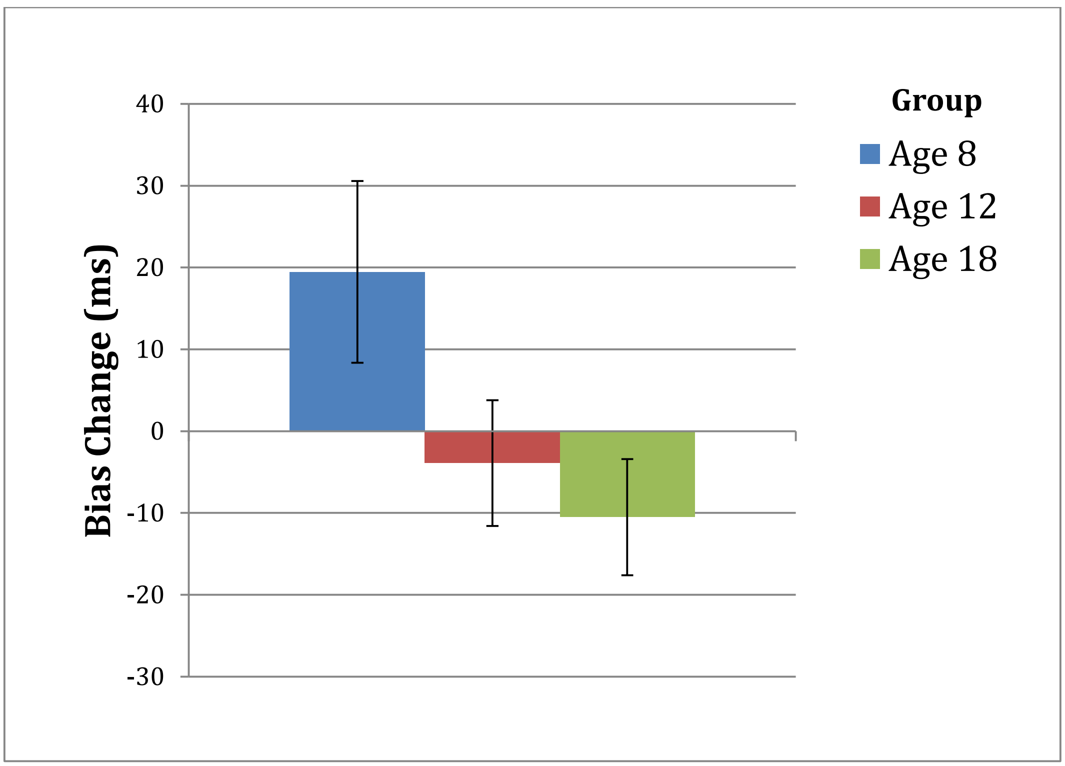

Figure 3. Bias Change by Age Group

5.2 Age Differences in Relations Between Bias Change and Stress Reactivity

Correlations between bias change and stress reactivity within each age group were examined. For stress reactivity, within the 12-year old group, bias change was positively correlated with depression ratings of stress reactivity, $r(27) = .54$, $p < .01$. Larger bias change toward threat was related to larger self-report of depression from before to after giving the speech. This correlation was significantly different than the 8-year old group ($Z = 2.42$, $p = .02$) but not significantly different than the correlation in the 18-year old group ($Z = 1.04$, $p > .05$) (See Figure 4). There were no significant correlations between anxiety stress reactivity and bias change within any of the age groups.

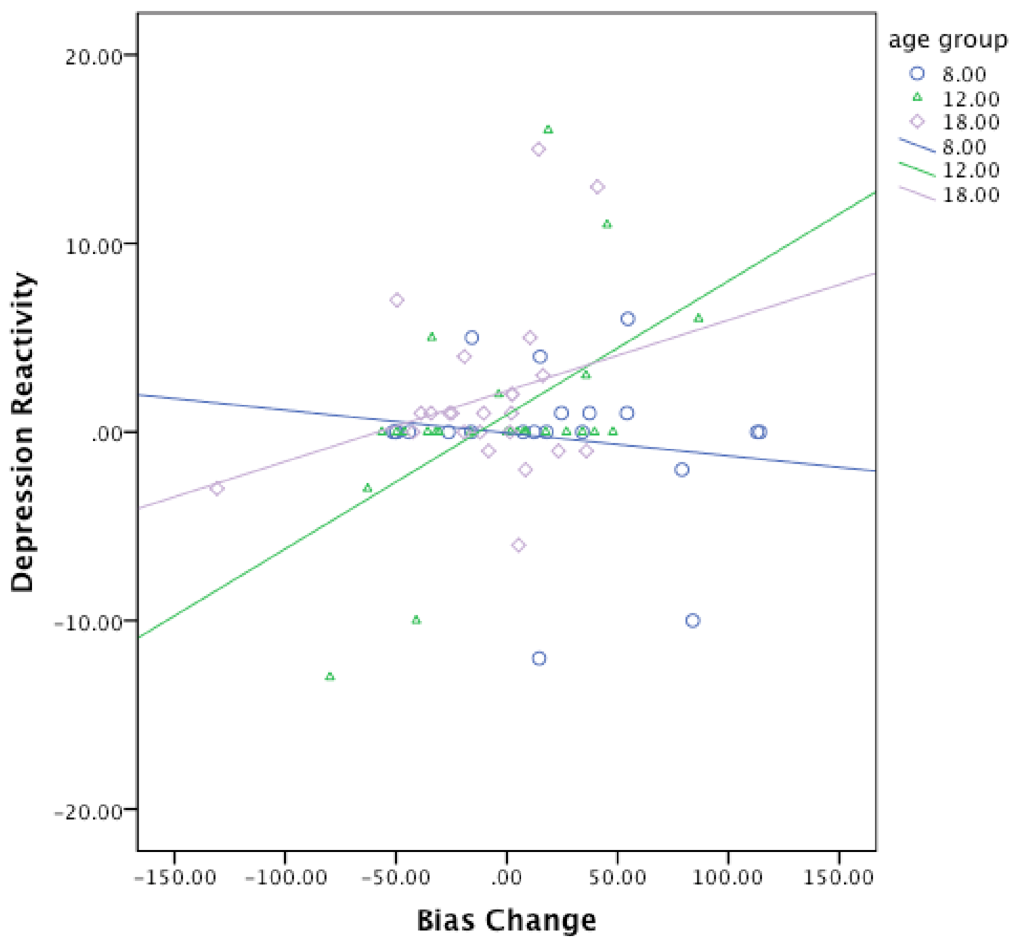

Figure 4: Correlation between Bias Change and Reactivity for Each Group

5.3 Relations Between Pubertal Development and Bias Change and Stress Reactivity

An ANCOVA was used to compare the bias change means of the created puberty groups (early, mid, and advanced), while controlling for age in months. This test was not statistically significant, $F(2,68) = 1.70$, $p = .19$. ANCOVAs were also run to examine stress reactivity between the puberty groups (early, mid, and advanced) while controlling for age in months. For anxiety reactivity, this test was not statistically significant, $F(2,69) = 2.55$, $p = .09$. As well, the ANCOVA with depression reactivity was not statistically significant, $F(2,69) = .53$, $p = .59$.

We then examined the relations between the continuous measure of pubertal development and bias change. We found a significant correlation between pubertal development and bias change, $r(70) = -.33$, $p < .01$ (See Figure 5). This suggests that lower levels of pubertal development were associated with greater threat-bias acquisition. Follow up partial correlations were conducted to examine whether pubertal development related to bias change irrespective of age. When controlling for age in months, there was still a significant negative correlation between pubertal development and bias change, $r(69) = -.25$, $p = .04$.

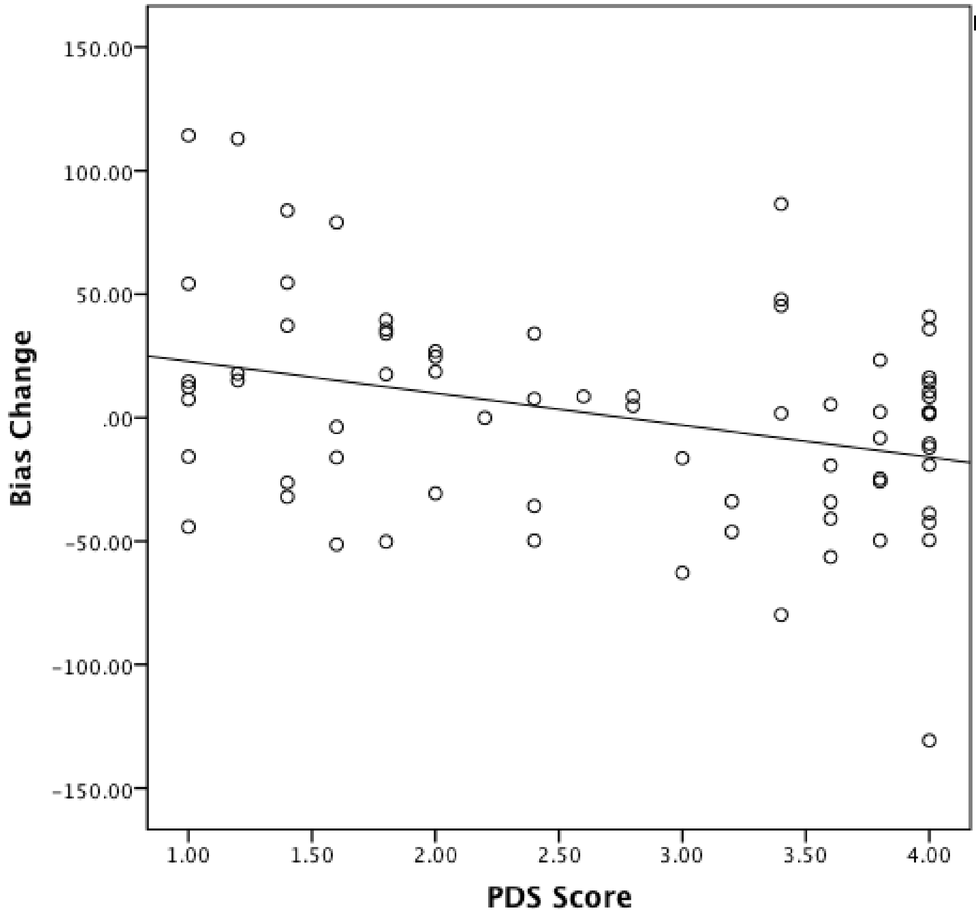

Figure 5: Correlation between Bias Change and PDS Scores

Correlations were then conducted between pubertal development scores and the stress reactivity scores (mood scale 4 – mood scale 3). Results revealed a significant correlation between pubertal development and anxiety ratings of stress reactivity, $r(71) = -.33$, $p < .01$. This suggests that the greater levels of pubertal development were associated with decreases in reported anxiety from the speech preparation to after giving the speech. This correlation remained significant when controlling for age in months, $r(68) = -.33$, $p < .01$. There were no relations between pubertal development and depression ratings of stress reactivity.

5.4 Pubertal variation within 12-year old group

As expected, the 12-year old group displayed the greatest pubertal variability (See Figure 6 and Figure 7). A median split on pubertal score was run within this age group. There were no group differences in bias change between the advanced and early pubertal 12-year old groups, $t(25) = 1.34$, $p = .19$. There were no group differences between the early and advanced pubertal 12-years olds in anxiety ratings of stress reactivity, $t(25) = 1.47$, $p = .15$ or in depression ratings of stress reactivity, $t(25) = .94$, $p = .36$.

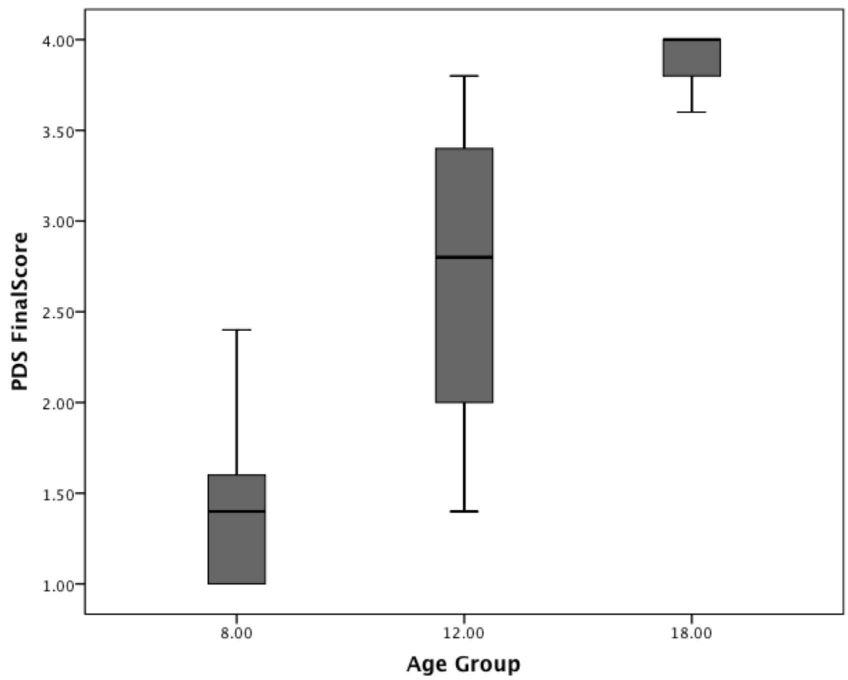

Figure 6. Pubertal Development Scores by Age Group

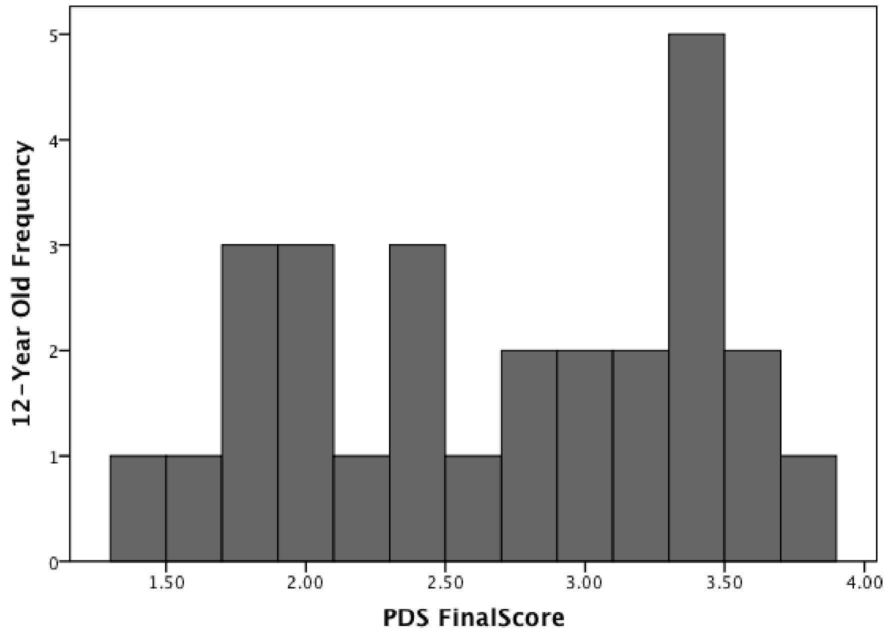

Figure 7. Histogram of PDS Frequency for 12-year olds

Correlational analyses were then run within the 12-year old groups to examine the relations between bias change and stress reactivity. Within the advanced pubertal 12-year olds, bias change was positively correlated with depression ratings of stress reactivity, $r(12) = .65$, $p = .01$. Greater bias change toward threat was related to greater self-report of depression from before to after giving the speech. This correlation was not significantly different than the earlier pubertal 12-year old group ($Z = 1.34$, $p > .05$). There were no significant correlations between anxiety ratings of stress reactivity and bias change within the earlier or advanced developed 12-year olds.

5.5 Age Differences in Relations Between Index of Trait Anxiety/Fearfulness and Bias Change

We examined whether our index of trait anxiety/fearfulness was related to bias change within each age group. There were no significant correlations between trait anxiety/fearfulness and bias change in the 8-year old group ($r(19) = -.09$, $p = .69$), the 12-year old group ($r(25) =.10$, $p = .61$) or in the 18-year old group ($r(22) = .08$, $p = .73$).

5.6 Age Differences in Relations between Social Sensitivity and Bias

Lastly, we examined whether social sensitivity related to bias change within each group. There were no significant correlations between social sensitivity and bias change in the 8-year old group ($r(19) = -.35$, $p = .13$), the 12-year old group ($r(25) = .14$, $p = .49$) or in the 18-year old group ($r(22) = -.05$, $p = .81$).

Chapter 6. Discussion

The primary goal of this study was to examine possible differences in threat bias acquisition across development. The current study aimed to 1) examine if threat bias could altered in 8, 12, and 18-year old children and explore possible age-related differences in threat bias acquisition 2) examine age-related differences in the relations between bias change and stress reactivity 3) examine pubertal development and its possible relations to bias change and stress reactivity and 4) explore temperamental traits and their possible relation to threat bias acquisition. To address these aims, the current study utilized an attention bias modification (ABM) with three age groups (8-year-old, 12-year-old, and 18-year-old children) to train attention allocation toward threat-related stimuli. After training, participants underwent a stress task and were assessed on emotional reactivity to stress. Data were also collected on pubertal development, trait anxiety, trait fearfulness, and social sensitivity.

Overall, the results indicated that the training paradigm was partially successful in altering children's threat bias, however, age was related to bias change. Results indicated that participants, regardless of age group, responded faster on the dot-probe task over time, suggesting the training procedure increased vigilance to threat. Results did not show a main effect of bias change from pre-training to post-training; however, there was a significant age group difference in threat bias acquisition. The 8-year old group displayed a greater threat bias change than did the 18-year old group. In partial support of the hypotheses, findings suggested that there were some group differences between stress reactivity and bias change. As well, decreases in anxiety reported stress reactivity after completion of a speech task were associated with more advanced pubertal development. Lastly, while pubertal development scores correlated with threat bias acquisition, self-reported temperamental trait characteristics did not relate to threat bias acquisition. A more detailed discussion of the current findings is provided below.

6.1 Threat Bias Acquisition and Age

Results from the current study indicate a significant age difference in threat bias acquisition. Contrary to our initial hypothesis, the youngest age group (8 years of age) demonstrated the greatest change in threat bias. Their mean bias change of 19.45 ms was significantly greater than the bias change in the 18-year old group. The mean bias change of the 12-year olds did not statistically differ from either group. Our initial hypothesis was based on previous research showing increases in rates psychopathology during adolescence and young adulthood (e.g., Anderson & Teicher, 2008). We thought that this developmental shift might be related to the ease at which a threat bias is acquired. However, the current results suggest that threat bias may be less malleable in the older children and more easily trained during early development.

This finding suggesting developmental differences in the ease in which children acquire a threat bias has major theoretical and practical implications. If attention bias is more malleable in younger children, targeted anxiety prevention and intervention may be most effective during these earlier years. Studies on training attention bias away from threat as a means to reduce anxiety symptoms is an ever-expanding literature. Indeed, there are at least two meta-analyses of the success of ABM treatment for anxiety disorders that show a modest effect size for this approach (Beard, Sawyer, & Hofmann, 2012; Hakamata, et al., 2010). However, while it is an exciting prospect to reduce pediatric anxiety via bias training, it remains unclear whether there are developmental differences in threat bias and anxiety relations and/or differences in the malleability of attention bias in children. The findings from the current study therefore offer initial support that there are indeed important developmental considerations that may influence the success of bias modification in children

The findings that threat bias modification was more easily achieved in younger children may suggest that the plasticity of attention bias toward threat is more malleable in earlier childhood and may decrease over development. This is in line with work on greater overall plasticity in youth (Nelson, 1999). This is not to say that attention bias isn't malleable in older youth and adults, as previously seen in successful training studies (see Bar-Haim, 2010 for review). However, the ease at which bias can be manipulated may change over development. The current findings suggest that attention bias prevention and intervention studies using ABM may be most effective in early to mid childhood. Indeed, age 8 is prior to the mean age of anxiety onset (Kessler et al., 2005) and may represent a key period in the formation of threat bias. Future developmental studies in this area may enhance the possibility of treatment and intervention development for pediatric anxiety.

6.2 Age Differences in Relations Between Threat Acquisition and Stress Reactivity

The current study examined emotional reactivity to a stressor. The 12-years olds were the only age group in which a significant relation between bias change and stress reactivity were detected. Counter to the initial hypotheses, no group differences were detected in the relations between bias change and anxiety symptoms. Interestingly, however, relations between bias change and depressive symptoms were detected. Specifically, greater threat bias acquisition was associated with greater stress reactivity to the speech task, as indexed by increased depression ratings, in the 12-year old group. This same relation was not detected in the other two age groups.

While a large portion of the social information processing bias literature has focused on anxiety, there have been a growing number of studies on the relations between attention bias toward threat and depressive symptoms (Baert, De Raedt, Schacht, & Koster, 2010; Wells & Beevers, 2010). MacLeod and colleagues found that training attention toward threat in adults was related to increased mood reactivity toward the stressor, but this was not modified by scale type (anxiety or depression ratings). Eldar and colleagues (2008) trained non-anxious children either toward or away from threat and found that both groups reported increased depressive ratings after a stress induction. In the current study, we aimed to examine possible developmental differences in these relations. To our knowledge, these findings are the first to examine and find significant age differences in the relation between stress reactivity and bias change.

The current study showed that the positive correlation between bias change and depressive ratings of stress reactivity was significantly stronger in the 12-year old group than the 8-year olds. It is possible that the overall association between threat bias and stress reactivity is weaker in younger children and is more robust later in development. In a study using latent class regression with 4 to 12 year olds, anxiety-related effects on emotional vigilance were found in the older but not the younger children (Broeren, Muris, Bouwmeester, Field, & Voerman, 2011). Further research is needed in order to elucidate the relations between bias acquisition and stress reactivity across development.

6.3 Pubertal Variation

Puberty marks a developmental period of heightened vulnerability for the onset and intensification of anxiety and depression problems. Research has suggested that puberty might exacerbate pre-existing vulnerabilities and the current findings suggest that perhaps the best time to target mental health prevention in youth is before pubertal development. The current study found significant relations between acquisition of threat bias acquisition and a child's pubertal status. When looking at the overall correlation between puberty scores and bias change, we did find a significant correlation, such that lower pubertal development was associated with greater bias acquisition. In attempt to disentangle age from puberty, we also ran a partial correlation in which we controlled for age in months. Results revealed that irrespective of age, pubertal development was negatively correlated with threat bias acquisition. Similar to our age difference results, we interpret these findings as evidence for greater ease of attention bias malleability in early development.

It should be noted that when splitting up the entire sample into three pubertal groups, results indicated that there were no pubertal group differences in bias change or stress reactivity when controlling for age. It is difficult to fully disentangle age and puberty, as these variables are highly related. It is possible that the null ANCOVA findings were due to decreased power and a larger scale study might be able to reveal possible pubertal group differences.

Significant effects of pubertal status were also detected when examining the relations between bias acquisition and stress reactivity. Specifically, results revealed a negative correlation between pubertal development and speech anxiety reactivity; this finding remained significant when controlling for age. One possible explanation for these findings is in terms of stress recovery. Later developed participants may report decreased anxiety from before to after the speech task because the stressor had been completed and was no longer an impending concern. Future studies should consider further probing self-reported symptoms in order to better understand possible rationale for changes in stress reactivity.

The wide variability of pubertal status in the 12-year olds provided a marked ability to examine the role of pubertal development separate from the effects of age. A median split on pubertal development was performed for the 12-year old group to create high and low pubertal subgroups. No group differences in bias change were found. Within the advanced pubertal 12-year olds, bias change was positively correlated with depressive reactivity to the speech task. However, this correlation did not significantly differ from that of the lower pubertal developed 12-year olds. We looked within our middle age group due to their greater pubertal variability, but our reduced power likely contributed to our null results. Given our strong puberty findings in the entire sample, further research may want to examine pubertal variation within a larger sample of a narrow age group.

6.4 Age Related Trait Characteristics and the Relations To Bias Acquisition

Contrary to our hypotheses, bias change did not correlate with our index of trait anxiety/fearfulness or social sensitivity within any of the age groups. While our main variable of interest was bias change, our hypotheses with trait characteristics were based on previous studies that found relations between threat bias and anxiety in children (see Puliafico & Kendall, 2006 for review). However, several studies have failed to detect relations between threat bias and trait anxiety in children (e.g., Brown et al., 2013;

Waters, Lipp, & Spence, 2004). Similarly, Broeren and colleagues (2011) did not find that threat bias related to behavioral inhibition or to anxiety and a meta-analysis found that attention bias in children was only related to clinical levels anxiety and not self-reported levels of heightened anxiety (Bar-Haim, et al., 2007).

Another possibility for the current findings is that bias acquisition is better for predicting future as opposed to concurrent trait measurements. Or perhaps more in line with Pérez-Edgar and colleagues (2010), an interaction would best explain the developmental effects of bias. For example, future work could examine whether the interaction between threat bias acquisition and childhood trait characteristics predict later psychopathology.

It is also important to consider that our null results on trait characteristics may be due to our use of child self-report. Children may have difficulty in reporting accurate emotional symptoms, thus making it difficult to detect associations with bias change. Future research may benefit by collecting both child and parent report questionnaires for the younger participants. However, previous work has found that parent and child report often show poor concordance (De Los Reyes et al., 2011).

6.5 Limitations and Future Directions

The current findings should be considered in light of several limitations. The sample size was modest; a larger sample would allow for greater examination of individual differences across development. As well, the current study used three set age groups to examine developmental factors linked to threat bias acquisition. This approach may limit the ability to discover important developmental factors associated with plasticity of threat bias. To address this limitation future work should use additional age groups or examine age as a continuous factor. Additionally, the current study was comprised of only female participants, thus the current results may not generalize to males. This is especially true for the pubertal development findings. As well, the current study did not include a control group who completed the dot-probe task without the contingency used in the active training. This was not necessary for our primary aim to examine age differences in bias acquisition, but the use of non-active ABM as a comparison in future studies may contribute to the ease of study interpretation.

There are also possible limitations in the measures used in the study. As previously mentioned, child self-report may not be most accurate method to assess trait characteristics and symptoms of mood and anxiety. As well, the use of the dot-probe study to examine threat bias in youth may be limited. Difficulties in measuring attention bias change in bias modification studies are not uncommon and may reflect particular aspects of the paradigm used (the dot probe task) rather than a true lack of change in attention-related patterns due to training. This may be especially relevant for developmental research. For example, a recent study examining the psychometric properties of paradigms used to assess biases in children found behavioral instability of bias measurements and low temporal stability (Brown, et al., 2013). The current assessment of threat bias relied on reaction times and since reaction times in children are more variable than in adults this may increase the chances of measurement error (A. M. Waters, et al., 2004). Indeed, the current results also capture the large variability in threat biases. It would be beneficial for future studies to consider the use of additional bias assessment tasks and examine the convergent results on attention.

While the dot-probe paradigm is most commonly used to assess and train attention bias, future studies should examine additional methods of measurement. For example, Schechner and colleagues (2013) utilized eye tracking to examine youth attention bias during a passive viewing paradigm. In light of the recent work on the limitations of RT tasks for attention bias assessment (Brown et al., 2013), the use of imaging and psychophysiological assessments may help us better understanding the underlying developmental processes involved in bias acquisition. Hardee and colleagues (2013) found that young adults who were behaviorally inhibited in childhood displayed greater attentional threat related fronto-amygdala activity than did non-behaviorally inhibited young adults.

Future developmental bias research may also benefit from the use of adaptive behavioral paradigms. As further supported by the current findings, there is great variability in attention bias toward threat. This is true in both clinical and normative populations. There have been positive outcome effects found in studies training participants' attention toward threat as well as in training attention away from threat. Studies have found that initial bias predicts stress reactivity (Wald et al., 2013) and the use of a pre-bias as participant selection criteria may help with study interpretations. The use of adaptive tasks may also be beneficial in training attention bias. Bernstein and Zvielli (2014) successfully used a novel attention training paradigm that provided individualized feedback to participants. Past research suggests that RT variability may decrease with age (Broeren et al., 2011), but perhaps the use of adaptive tasks would prove helpful for youth, especially for younger children who may struggle with task comprehension and performance.

6.6 Conclusions

The current study provided a descriptive account of the relations between bias change, stress reactivity, pubertal development, and trait characteristics between three age groups. While it is clear that more work is needed to further elucidate the developmental differences in threat bias malleability, the current findings showing developmental differences in the ease in which threat biases were acquired have important implications for pediatric prevention and intervention research. While the current study suggests that the relations between threat bias acquisition and stress reactivity may be more robust in older children, bias trainability was greater in the 8 year olds. This suggests that earlier targeted bias treatments for prevention and intervention studies may be most successful during the elementary years. However, the current study examined threat bias acquisition, thus future work needs to examine these developmental associations in the context of ABM to test age differences in the ability of children to extinguish threat biases (e.g., acquire biases away from threat) .

In sum, the current study demonstrated age differences in threat bias acquisition and its' relations to puberty and stress reactivity. The 8-year old group showed the greatest acquisition of an attention bias toward threat. Pubertal development was also a unique predictor of bias change. However, the 12-year olds displayed significantly greater relations between bias acquisition and stress reactivity in comparison to the youngest group. The current findings coupled with the above discussion emphasize the need for additional developmental research on attention bias malleability. Longitudinal work might prove especially useful in our continued understanding of the relations between developmental bias acquisition and stress reactivity, physical development, and anxiety-related trait characteristics. While there is a clear need for the continued study of ABM across development, the current study is one of the first to show age differences in threat bias acquisition and its' relations to stress reactivity and pubertal development.

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