Plasticity in attention: Implications for stress response in children

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Abstract

Attention bias has been suggested as an etiological and maintaining factor in anxiety. However, empirical evidence establishing this causal association is scarce and has been provided only in adults. In this preliminary study, we tested whether an induction of attentional bias can cause changes in vulnerability to stress in children reporting normal anxiety levels. Twenty-six 7–12 year-old children were randomly assigned to two groups. One group was exposed to a training condition designed to induce an attentional bias away from threat. The other group was exposed to a training condition designed to induce an attentional bias toward threat. Children who were trained to attend to threat developed attentional vigilance to threat-related information. The training procedure was ineffective with children who were trained to avoid threat, and their attention remained unbiased. Children from both training groups reported elevated depression scores following stress-induction. However, only the children who were trained to attend to threat subsequently reported elevations in anxiety. The findings suggest that biased attentional responses to threat, among children, can exert a specific influence on the tendency to experience anxiety in the face of stress.

Keywords: Attention Bias; Training; Anxiety; Threat; Faces; Children

Introduction

The normative anxious-vigilant state associated with processing of potential danger in the environment helps people respond promptly and effectively to threat. Consequently, facilitated processing of threat-related stimuli has a clear adaptive value for survival. However, excessively biased processing of threat-related material might lead to the experience of more frequent and longer periods of unwarranted anxiety. The notion that processing biases play a prominent role in the etiology and maintenance of anxiety (e.g., Eysenck, 1992, 1997; Lonigan, Vasey, Phillips, & Hazen, 2004; Williams, Watts, MacLeod, & Mathews, 1997) fostered intensive research, which in general provides convincing evidence for the view that the attentional system of anxious individuals is biased in favor of threat-related stimuli (for reviews see Bar-Haim, Lamy, Pergamin,
Bakermans-Kranenburg, & van IJzendoorn, 2007; Mogg & Bradley, 1998). However, empirical evidence establishing the causal nature of this correlation is still remarkably scarce.

A number of studies have shown that when clinical anxiety is successfully treated attention biases diminish or even disappear altogether (e.g., Lavy, Vandenhouw, & Arntz, 1993; Mathews, Mogg, Kentish, & Eysenck, 1995; Mattia, Heimberg, & Hope, 1993). Although such findings may be taken to suggest that threat-related attention biases are mere correlates of anxiety, in effect, studies using this design cannot rule out the possibility that attentional biases do serve as predisposing or maintaining factors in anxiety. As pointed out by Mathews and MacLeod (2002), the only decisive method of testing whether an attentional bias can cause anxiety is to effectively manipulate attention and consequently measure the effect of this manipulation on anxiety. To our knowledge, only one set of studies took this approach using modified versions of the dot-probe task (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002; Mathews & MacLeod, 2002).

In the classical dot-probe task (MacLeod, Mathews, & Tata, 1986) two stimuli, one threat related and one neutral are shown on each trial, and their offset is followed by a target probe, which appears with equal probabilities at the location just occupied by one of them. Participants have to respond as fast as possible to the probe. Response latencies provide a “snap-shot” of the distribution of participants’ attention, with faster responses to probes presented at the attended relative to the unattended location (Navon & Margalit, 1983). Attention bias towards threat is inferred when participants respond faster to probes replacing threat related rather than neutral stimuli. The opposite pattern indicates avoidance of threat. Threat-related attentional bias on the dot-probe task was found in anxious children and adults but not in non-anxious participants (Bar-Haim et al., 2007 for a review).

MacLeod et al. (2002) examined the effects of attentional training on state anxiety. Following a baseline measurement of attentional bias in a classical dot-probe task with word stimuli, adult students were randomly assigned to one of two training conditions. One condition was intended to induce an attention bias towards threat by presenting most of the target probes at the location of the threat-related words. The other condition was intended to induce avoidance of threat by presenting most of the target probes at the location of the neutral words. Results showed that both types of training induced an attentional bias concordant with the training condition. This induction of attention bias in itself did not produce any measurable changes in anxiety, but modified the degree to which participants reported experiencing a negative emotional response (depression and anxiety) to a subsequent stressor task. These results support the hypothesis that attentional bias to threat can induce an emotional vulnerability to stress.

Using the same modified dot-probe procedures, Mathews and MacLeod (2002) also reported that high trait-anxious individuals, who were extensively trained to avoid threat words, showed a decrease in trait anxiety relative to a pre-training assessment. No such change in trait anxiety was observed in a control group of high trait-anxious adults who completed a set of placebo training sessions using the classic dot-probe task, in which the probe was equally likely to appear at the location of the threat related or of the neutral stimulus.

The demonstration by MacLeod and colleagues (MacLeod et al., 2002; Mathews & MacLeod, 2002) that attentional training can influence emotional vulnerability to stress has important practical and theoretical implications. Specifically, the finding that the dot-probe task, with slight modification, may be used as a computerized tool for modifying attention deployment patterns is an important step for potential translation of the accumulating science implicating attentional biases in anxiety to an effective intervention.

Compared with the adult literature a relatively small number of dot-probe studies have been completed with anxious children (e.g., Brotman et al., 2007; Dalgleish, Moradi, Taghavi, Neshat-Doost, & Yule, 2001; Dalgleish et al., 2003; Hunt, Keogh, & French, 2007; Monk et al., 2006; Pine, Klein et al., 2005; Pine, Mogg et al., 2005; Reid, Salmon, & Lovibond, 2006; Taghavi, Neshat-Doost, Moradi, Yule, & Dalgleish, 1999; Vasey, Daleiden, Williams, & Brown, 1995; Vasey, ElHag, & Daleiden, 1996; Watts & Weems, 2006), and these indicate that children as young as 7 years can perform satisfactorily on the dot-probe task. However, to our knowledge, no study has yet used attention training in children to test for causal associations between attentional bias and vulnerability to stress.

The purpose of the present study was to test whether the findings of MacLeod et al. (2002) in adults could be replicated with 7–12-year-old children reporting normal levels of anxiety. Following a preliminary assessment of attention allocation patterns on a classic dot-probe task, children were randomly assigned to one of two groups who performed on a modified dot-probe task. For each group, systematic contingencies were arranged...
between stimulus and target-probe positions, in order to induce an attentional bias either toward or away from threat. The efficacy of these attentional training procedures was assessed by examining response latencies on a subsequent dot-probe session, within which the training contingencies were eliminated. Following this attentional training procedure, the children were exposed to a brief stress-inducing manipulation, and individual differences in emotional vulnerability were measured as the degree of change in self-reported depression and anxiety and the frequency of stress-related behavior during the stressor task.

Following MacLeod and his colleagues we expected that the attentional training procedures would induce biased attentional responses to threat information, and affect emotional vulnerability accordingly. Specifically, we expected that relative to children trained to attend away from threat, children trained to attend toward threat would display greater elevations in anxiety and depression in response to the stress-inducing manipulation. Unlike the adult studies by MacLeod et al. that used threat and neutral word stimuli, we used pictures of angry and neutral facial expressions as our threat and neutral stimuli (for studies with children using a dot-probe task with face stimuli see Brotman et al., 2007; Monk et al., 2006; Pine, Mogg et al., 2005). We selected face stimuli rather than words to avoid potential confounds related to variability in children’s reading skills, and to increase the ecological validity of the stimuli (for a discussion of this issue see Bradley, Mogg, Falla, & Hamilton, 1998).

Method

Participants

Twenty-six children aged 7–12 years ($M = 9.40$, $SD = 1.63$) volunteered to participate in this study, with the consent of their parents. Participants were selected to show normal levels of anxiety at the start of the experiment. Thus, relying on Spielberger’s trait anxiety scale of the State-Trait Anxiety Inventory for Children (STAIC, Spielberger, Edwards, Lushene, Montuori, & Platzek, 1973), only children with trait anxiety scores within 1 standard deviation from the norm were included. The participants were randomly assigned to two groups. One group of participants was exposed to a training condition designed to induce an attentional bias away from threat (angry faces). The other group was exposed to a training condition designed to induce an attentional bias toward threat. The groups did not differ in age ($M = 9.63$ years, $SD = 1.81$ and $M = 9.31$ years, $SD = 1.52$ for the group trained away from threat and the group trained toward threat, respectively). The groups did not differ on trait anxiety scores before training (Table 2). And, male-to-female ratio was the same in both groups (9 boys and 4 girls).

Emotional assessment instruments

State-Trait Anxiety Inventory for Children (STAIC)

The STAIC (Spielberger et al., 1973) consists of two 20-item scales completed by the child and measuring both enduring tendencies to experience anxiety (trait anxiety) and situational variations in levels of perceived anxiety (state anxiety). The translation of these scales to Hebrew was done according to the instructions of Spielberger and Díaz-Guerrero (1976), and was found to be reliable and valid for use with Israeli children (Teichman & Melinic, 1979).

Analog mood scales

As in MacLeod et al. (2002), we used two analog mood scales to assess the levels of negative mood state before and after stress induction. The scales were programmed for computer delivery. Each scale consisted of a 15 cm horizontal line, divided into 30 equal-sized partitions. One analog scale displayed the terminal labels “relaxed” and “anxious” (the analog anxiety scale), and the other displayed the terminal labels “happy” and “sad” (the analog depression scale). Children used the computer mouse to move a cursor along the line to a point corresponding to their current mood state. This yielded a score between 1 and 30 depending on which partition of the line was selected. Higher scores indicated a more anxious or depressed state.
Behavioral index of unease/stress during the stress-induction task

Children’s stress-related behavior during the stress-induction task was coded. Due to the nature of this task, in which children were seated in front of a table, looking down, and typically using both their hands, only a limited number of behaviors were relevant for coding. We selected behaviors that in our mind - possessed face validity as indicators of unease and agitation. These behaviors were: negative vocalizations (e.g., “oh no”, “I can’t solve it”, “this is hard”), negative head movements (i.e., repeatedly moving the head left and right—a clear negative non-verbal motion), major postural changes (e.g., standing up or leaning all the way backwards, which we interpreted as reflecting unease and attempts to relieve tension), and gazing away from the task (which we interpreted as a behavioral attempt at disengaging from the stress induced by the task, in some instances, or as looking for affirmation and conciliation from the experimenter, in other instances). The stress-induction task lasted 3 min. Coding was conducted within 10 s intervals in which the occurrence of each behavior was coded (18 intervals in total). One third of the video tapes were independently coded by two graduate students and one post-doctorate fellow who were blind to children’s training condition. Percent agreements for the entire coding matrix ranged from 93% to 99%, mean Kappa for the negative vocalizations, negative head movements, major postural changes, and gazing away from task codes were 0.70, 0.86, 0.66 and 0.88, respectively.

Principle components analysis revealed that the scales loaded on two factors with eigenvalues greater than one, which together explained 70.95% of the variance. One factor loaded the codes for negative vocalizations and negative head movements (Cronbach’s $z$ for the combined scale = 0.79), the other factor loaded the codes for major postural changes and gazing away from the task (Cronbach’s $z$ for the combined scale = 0.69). Because these two combined scales showed nearly significant correlation, $r$(24) = 0.31, $p = 0.07$, we also computed a combined behavioral index of stress/unease by summing the occurrence of the four coded behaviors.

The dot-probe task

Experimental stimuli

The face stimuli consisted of chromatic photographs of 12 different Caucasian actors (6 male, 6 female) taken from the NimStim stimulus set.1 Two different pictures of each individual were selected, one depicting an angry facial expression and the other depicting a neutral expression. Participants were presented with pairs of neutral–angry faces, comprised of pictures of the same person. Each face photograph subtended 55 × 80 mm$^2$. The faces were presented at equal distances to the left and right of a fixation cross located at the center of the screen, with a distance of 16.5 cm from the center of one face to the center of the other.

Dot-probe task procedure

Fig. 1 presents the sequence of events in the dot-probe task. Each trial began with the presentation of a fixation cross (2 × 2 cm$^2$) at the center of the screen for 1000 ms, which was followed by a face pair display for 700 ms. Following the display of faces, a target probe appeared for 100 ms, after which the screen went blank. The target-probe display consisted of two dots distant from each other by 5 mm center-to-center. Each dot subtended 2 mm in diameter. The dot pair was oriented either horizontally (· ·) or vertically (;) and appeared at a distance of 8.5 cm either to the left or to the right of fixation (center-to-center), that is, at the location of the center of either the left or the right photograph of each face pair. Participants had to determine the orientation of the dots (horizontal or vertical) by pressing one of two pre-specified buttons on a response box. A new trial began 1400 ms after target-probe offset.

The pictures of the 12 different individuals selected from the NimStim set were divided into two face pair subsets, each of which consisted of 6 pairs (3 male, 3 female). For any given participant, only one subset of face pairs was used during the pre-training and the attention training phases (old faces). In the post-training assessment, in addition to the old set of faces, participants were presented with the other set (new faces).

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1Development of the MacBrain Face Stimulus Set was overseen by Nim Tottenham and supported by the John D. and Catherine T. MacArthur Foundation Research Network on Early Experience and Brain Development.
The subset of pictures to be used for the pre-test and the attention training phases as well as the order of subsets presentation during the post-training phase were counterbalanced across participants.

**Experimental trials in the pre-training and post-training phases**

The pre-training session consisted of 96 trials, divided into two blocks of 48 trials each. The post-training phase consisted of 192 trials, divided into four blocks, two of which included the old faces set, with the other two including the novel faces set. Each condition of emotion face location, probe location, probe orientation, and gender of face was equally probable within each block.

**Experimental trials in the attention training phase**

Children received two training sessions of 336 dot-probe discrimination trials each (672 trials in total), according to their designated training condition. In the condition of training attention towards threat, children were presented with angry–neutral stimulus pairs followed by target probes always appearing at the location of the angry face. In the condition of training attention away from threat children were presented with angry–neutral stimulus pairs followed by target probes always appearing at the location of the neutral face.

**Stress-induction task**

The purpose of this task was to elicit a negative mood state. The children were informed that they would be videotaped while attempting to complete three difficult puzzles taken from the game Rush Hour Traffic Jam Puzzle®. One puzzle was solved with the child as an example. Then the video camera was turned on and the children were told that they had 3 min to complete the three remaining puzzles. After 3 min, the child was told to stop. None of the children succeeded in solving all three puzzles within the allocated time.
General procedure

The procedures for this study were approved by the institutional review board. Each child was seen individually, in a quiet room, at his or her home. The procedure consisted of two sessions conducted on 2 separate days with no more than 6 days elapsing from the first session to the next. At the beginning of the first session parents and children were given a detailed description of the experiment and written informed consents were obtained from both. Then, each child completed the STAIC and the analog mood scales. The session proceeded with instructions for the dot-probe task and some practice trials. Children then completed the 96 pre-training trials, followed by the first 336 trials of training, which were presented in seven blocks of 48 trials each. The second meeting started with the completion of 336 additional training trials, after which the child was asked to complete the STAIC and to respond to the analog mood scales again. Then the 192 post-training dot-probe trials were administered (96 trials of old pictures that were used for the pre-training and the training trials, and 96 trials with new pictures). Following the completion of the post-test trials and just before the stress-induction task, each child was asked to complete the analog mood scales again. The 3-min stress-induction task was then delivered and followed by an additional completion of the analog mood scales.

At the end of these procedures the experimenter took the time to debrief the children explaining to them the purpose of the stressor task and assuring them that none of the other participants were able to solve the puzzles within the allocated time frame. Parents were asked to contact us with any additional questions concerning the study or if their child displayed any signs of excessive distress in the weeks following the study. No such calls were received. Finally, to further alleviate concerns regarding potential long-term negative effects of training non-anxious participants to attend to threat we contacted these participants 9–12 months after the study had ended. Children completed the trait anxiety scale of the STAIC and their parents were briefly interviewed about their child’s well-being.

Results

We first assessed whether the amended dot-probe task was effective in inducing differential attentional biases to the face stimuli according to the different training conditions. We then assessed whether the data collected from the analog mood scales and the behavioral observations reflected an emotional change following training of attentional allocation.

Probe discrimination latencies

The probe discrimination latencies for each attention training group under each experimental condition are presented in Table 1. Due to the chance entailed in random assignment of participants into the training groups, children who were trained to attend toward threat started the experiment with a numerically larger average bias away from threat than the children who were trained to attend to neutral (19 ms difference). However, this difference did not approach statistical significance, \( t(24) = 1.27, p = 0.22, \) \( \text{Cohen's } d = 0.52, \) and neither group showed an attention bias that was significantly different from zero, \( t(12) = 0.28 \) and \( 1.70, p's = 0.78 \) and \( 0.12, \) for the groups train toward neutral and toward threat, respectively.

For the main analyses, reaction time data were subjected to two separate \( 2 \times 2 \times 2 \times 2 \) mixed-design ANOVAs. Training Group (train to neutral, train to angry) and Post-Training Block Presentation Order (old faces first, new faces first) served as between-group factors, whereas Target Location (at the location of neutral, at the location of angry), and Test Phase (pre-training, post-training) served as a repeated measure factors. One ANOVA considered the effects of training on response patterns to the same face stimuli used during training (old faces); the other considered the novel face stimuli (new faces).

The only significant effect in the analysis concerning the old faces was a Test Phase by Target Location by Training Group three-way interaction, \( F(1, 24) = 5.21, p<0.05, \) \( \text{Cohen's } d = 0.93. \) Follow-up ANOVAs within each training group revealed a significant increase in attention bias toward threat in the group trained to attend to angry faces, reflected in a simple two-way Test Phase by Target Location interaction, \( F(1, 12) = 12.38, p<0.005, \) \( \text{Cohen's } d = 2.03. \) The attention training effect was non-significant for the participants who were trained to attend to neutral faces, \( F(1, 12)<1, \) \( \text{Cohen's } d = 0.25. \) Simply put, our
The analysis concerning the new faces revealed a similar but less robust pattern of results. A Test Phase by Target Location by Training Group three-way interaction at a trend level of significance was found, $F(1, 24) = 3.12$, $p = 0.09$, Cohen’s $d = 0.72$. Follow-up ANOVAs within each training group revealed a significant increase in attention bias toward threat in the group trained to attend to angry faces, as indicated by a Test Phase by Target Location interaction, $F(1, 12) = 4.91$, $p < 0.05$, Cohen’s $d = 1.28$. The attention training effect was non-significant for the participants who were trained to attend to neutral faces, $F(1, 12) < 1$, Cohen’s $d = 0.18$.

Emotional reactions to stress induction

As in the data reported by MacLeod et al. (2002), the induction of biased processing through training procedures did not yield observable changes in anxiety immediately after training (Table 2 for means and SEs). A set of comparisons between pre-training and post-training scores on the STAIC state and trait scales, and the anxiety analog scale, revealed non-significant Assessment Time by Group interactions, all $F$’s < 1, Cohen’s $d$’s = 0.08, 0.24 and 0.40, respectively. A non-significant Assessment Time by Group interaction was also found for the depression analog scale $F(1, 24) = 1.81$, $p = 0.19$, Cohen’s $d = 0.55$. Interestingly, the children in both training groups reported less depression following training ($M = 6.35$, SE = 1.02) than before training begun ($M = 8.81$, SE = 1.09), $F(1, 24) = 4.20$, $p = 0.052$, Cohen’s $d = 0.84$. This effect may reflect the relief associated with the completion of the training phase and the greater familiarity with the experimenter and the experimental setting.

A different pattern of results emerged when children had to face an emotional stressor. The scores obtained from the analog mood scales before and after the stressor task are presented in Table 3. These data were subjected to a mixed-design $2 \times 2 \times 2$ ANOVA that considered the between-group factor Training Group (train to neutral, train to angry) and the repeated measures factors Scale Type (anxiety scale, depression scale), and Assessment Point (pre-stress, post-stress). A significant main effect of Assessment Point was found, reflecting elevated negative mood following stress induction (4.60 pre-stress vs. 7.40 post-stress), $F(1, 24) = 9.92$, $p < 0.005$, Cohen’s $d = 1.29$. This effect confirms the efficacy of the stress manipulation. More importantly, this main effect was subsumed within a significant Training Group by Assessment Point by Scale Type interaction, $F(1, 24) = 9.03$, $p < 0.01$, Cohen’s $d = 1.23$. This interaction reflects the fact that the degree to which the stress manipulation elicited negative mood was modified in different ways for participants exposed to the different training conditions, and that it was differentially modified for the anxiety and the depression scales.
To explicate this higher-order interaction, separate ANOVAs were computed for the anxiety and depression scores. The ANOVA concerning the depression scores revealed a main effect of Assessment Point indicating that children from both groups were more depressed following stress induction ($M = 7.73$) relative to the pre-stress measurement ($M = 4.46$), $F(1, 24) = 9.79$, $p < 0.005$, Cohen’s $d = 1.28$. No other main or interaction effects regarding the depression scale approached significance. The ANOVA concerning the anxiety scores also revealed a significant main effect of Assessment Point, $F(1, 24) = 5.52$, $p < 0.05$, Cohen’s $d = 0.96$, which was subsumed, however, under an Assessment Point by Training Group interaction, $F(1, 24) = 4.17$, $p = 0.052$, Cohen’s $d = 0.83$. The nature of this interaction is presented in Fig. 2. Children who were trained to attend to angry faces showed increased anxiety following stress induction, $t(12) = 3.62$, $p < 0.01$, Cohen’s $d = 2.09$, whereas children trained to attend to neutral faces showed no change in anxiety from the pre-stress to the post-stress assessments $t(12) < 1$, Cohen’s $d = 0.11$.

Behavioral observation data were examined using two-tailed t-tests. Data for two children from the group trained to attend to neutral faces are missing due to technical failures of the video-recording equipment. Overall, children trained to attend to angry faces showed a higher frequency of stress-related behaviors during the stress-induction task relative to the group of children trained to attend to the neutral faces. Specifically, a significant between-groups difference emerged for the scale combining negative vocalizations and negative

<table>
<thead>
<tr>
<th>Training group</th>
<th>STAIC-trait Pre-training</th>
<th>STAIC-trait Post-training</th>
<th>STAIC-state Pre-training</th>
<th>STAIC-state Post-training</th>
<th>Depression analog scale Pre-training</th>
<th>Depression analog scale Post-training</th>
<th>Anxiety analog scale Pre-training</th>
<th>Anxiety analog scale Post-training</th>
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<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>SE</td>
<td>$M$</td>
<td>SE</td>
<td>$M$</td>
<td>SE</td>
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<td>SE</td>
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<td>1.10</td>
<td>6.85</td>
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<td></td>
<td>32.15</td>
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<td>6.69</td>
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<td>Train to angry</td>
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<td>27.31</td>
<td>1.10</td>
<td>5.85</td>
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<td>27.39</td>
<td>1.10</td>
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</table>

Table 2
Means and standard errors of State and Trait Anxiety Scores (STAIC), and depression and anxiety scores (analog mood scales) before and after attention training

<table>
<thead>
<tr>
<th>Training group</th>
<th>Depression analog scale Pre-stressor task</th>
<th>Depression analog scale Post-stressor task</th>
<th>Anxiety analog scale Pre-stressor task</th>
<th>Anxiety analog scale Post-stressor task</th>
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<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>SE</td>
<td>$M$</td>
<td>SE</td>
</tr>
<tr>
<td>Train to neutral</td>
<td>4.77</td>
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<td>4.15</td>
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<tr>
<td></td>
<td>9.00</td>
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Table 3
Means and standard errors for depression and anxiety (analog mood scales) before and after the stressor task
head movements, $t(22) = 2.21, p < 0.05$, Cohen’s $d = 0.94$. A nearly significant difference emerged for the scale combining major postural changes and gazing away from task, $t(22) = 1.92, p < 0.07$, Cohen’s $d = 0.82$. Finally, for the combined behavioral observation score, a significant training group effect was also found, $t(22) = 2.82, p < 0.01$, Cohen’s $d = 1.20$.

To assess whether our attention training toward threat might have induced long-term adverse effects, approximately 9 months after the study had ended, we contacted 10 out of the 13 participants who were randomly assigned to train attention toward threat and asked them to complete the trait scale of the STAIC again. The data indicate that all these children remained within the normal non-anxious range on this scale ($M = 35$, SE = 1.72) and that their scores did not differ from their scores from the beginning of the study, $t(9) = 1.13, p = 0.29$. In addition, parents did not report any concerns about the well-being of their children. We are therefore confident that our transient induction of threat-related attention bias was not traumatic to the children and did not have lasting effects on their anxiety levels.

**Discussion**

Following the initial reports by MacLeod et al. (2002) in adults, the purpose of the present pilot study was to test whether the attention allocation patterns of non-anxious children may be altered through an attention training procedure, and whether such changes, if achieved, correspond with modulations in anxiety and depression.

The pattern of change in probe discrimination latencies from pre-training assessment to post-training assessment indicates that the training procedure affected the responses of the children who were trained to attend to threat. Following training, these children developed a selective speeding to probes in the location of angry faces suggesting an attentional vigilance to threat-related information. This induced bias in attention was evident with the face stimuli used in the training trials, and showed a similar numerical trend with novel face stimuli. Effect size calculations suggest that both effects (i.e., with old and novel faces) are robust. By contrast, the training procedure was ineffective with the children who were trained to avoid threat and their attention allocation patterns before and after training remained unbiased. Such a ‘better safe than sorry’ policy of attention allocation to threat makes considerable sense from an evolutionary view point, as it may be more adaptive to have a rigid criterion for scaling down preset alertness thresholds even when threat is not currently processed.

The successful induction of attentional bias toward threat faces via training allows us to tentatively test for causal effects of attentional bias on anxiety and depression. As in the case of MacLeod et al. (2002) in adults, our analog anxiety and depression scales data indicate that increased attentional bias toward threat following
training had no direct effect on state depression and state anxiety immediately following the attention training procedure. However, these changes in attention appeared to modify children’s emotional vulnerability to a subsequent stressful event. Unlike MacLeod et al. who did not find differences between the modulation of depression and the modulation of anxiety following stress induction, our data revealed specificity. We found that while the children from both training groups reported elevated depression scores following stress induction, only the children who were trained to attend to threat subsequently demonstrated an increased tendency to experience anxiety.

This pattern of findings supports the hypothesis that biased attentional responses to threat in children can exert a specific influence on the tendency to experience anxiety (but not depression) in the face of stress. The divergent results for anxiety and depression in the present study stand in contrast to the findings of MacLeod et al. (2002), who reported both elevated depression and elevated anxiety following a stressor task in adults. The anxiety-related specificity found here may be related to the fact that comorbidity between anxiety and depression appears to intensify with age (Brady & Kendall, 1992; Pine, Cohen, Gurley, Brook, & Ma, 1998). However, further research is needed to settle this issue. The present findings also extend the association between attention bias and anxiety beyond participants’ self-reports, with behavioral observation data indicating elevated stress behavior during performance on the stressor task in the group of children trained to attend to threat.

One question left unanswered by the present study is how the pattern of anxiety results following stress induction might relate to a non-training baseline condition (e.g., repeated exposures to a classic dot-probe). It may be the case that relative to a non-training baseline condition the group trained to attend to threat showed increased vulnerability to stress, the group trained to attend to neutral showed reduced vulnerability to stress, or both. Future studies could introduce a third non-training control group to tap into this information. In addition, the present design and sample size did not afford us to perform a full mediation analysis testing the causal relations between changes in attention bias and changes in anxiety. Future studies, with larger sample sizes, could sequentially test predictors of the mediator (attention training), and thus provide important converging evidence for the inference of causality in the attention training–anxiety association (MacKinnon, Fairchild, & Fritz, 2006).

The results of the present study should also be viewed in light of potential limitations stemming from relatively small sample size. The sample size may have limiting our ability to detect the hypothesized effects in the group trained to attend to the neutral faces. A small numerical trend (8 ms) in the expected direction was found for the group trained to attend to neutral in the old faces condition. However, a small change (5 ms) in the opposite direction in the new faces condition was also found. Perhaps training non-anxious children to attend to neutral over threat stimuli requires more extensive training than that provided in the present study, a factor that might not be related to sample size. This concern for potential lack of power to detect training effects in the train to neutral group may be somewhat attenuated by the fact that the hypothesized effects were robustly detected in the group trained to attend toward threat.

Another point for consideration is related to the fact that the group trained to attend toward threat started the experiment with slower overall reaction times and with a greater mean bias away from threat relative to the group trained to attend to neutral. These between group differences in pre-training attention bias and in overall reaction times were impossible to control for in our random assignment design. Importantly, these random differences in pre-training bias were not significant and the biases away from threat in both groups were not significantly different from zero. That being said, this initially larger bias in the group trained to attend to threat may have accentuated our response time findings for this group. Future studies may be able to better control for such variations by either recruiting considerably larger samples or by employing matching procedures that take into account pre-training bias levels.

Finally, although the present study indicates that it may be difficult to induce an attention bias away from threat in non-anxious children displaying no bias to begin with, one may expect to overcome this floor effect with clinically anxious children who typically show significant attentional bias towards threat (Bar-Haim et al., 2007; Kindt & Van den Hout, 2001; Puliafico & Kendall, 2006). Thus, attention training procedures designed to reduce attentional bias in anxious children through redirection of their attention toward neutral or positive stimuli may prove effective in reducing vulnerability to stress. Preliminary clues for the potential of such intervention procedures have been provided by Mathews and MacLeod (2002) in high trait-anxious adults.
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