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Cascading Effects: The Influence of Attention Bias to Threat on the Interpretation of Ambiguous Information

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Abstract

Both attention bias to threat and negative interpretive bias have been implicated in the emergence and maintenance of anxiety disorders. However, relations between attention and interpretive biases remain poorly understood. The current study experimentally manipulated attention bias to threat and examined the effects of attention training on the way ambiguous information was interpreted. Results suggest that the preferential allocation of attention towards threat affects the manner in which ambiguous information is interpreted. Individuals trained to attend to threat were more likely than individuals in a placebo training group to interpret ambiguous information in a threat-related manner. These data suggest that perturbations in the initial stages of information processing associated with anxiety may lead to a cascade of subsequent processing biases.

Keywords

Anxiety; Attention bias; Attention training; Information processing; Interpretive bias

INTRODUCTION

Anxious individuals preferentially allocate their attention towards threat-related information in the environment (for a review, see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007) and interpret ambiguous information in a negative manner (for a review, see Mathews & MacLeod, 1994). Each of these two biases fundamentally shapes individual differences in anxiety (Mathews & MacLeod, 2002). However, despite a growing body of research examining these attention and interpretive biases, the relations between them remain unclear. Cognitive biases in attention and interpretation may be intricately related cognitive processes. That is, both biases may stem from a shared processing mechanism (Mathews, Mackintosh, & Fulcher, 1997; Williams, Watts, MacLeod, &

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Mathews, 1997) or one cognitive bias may have a direct influence on another cognitive bias (Hirsch, Clark, & Mathews, 2006). For example, attention bias, reflecting early threat-processing, may significantly influence interpretive bias, reflecting downstream processing (Crick & Dodge, 1994; Daleiden & Vasey, 1997; Muris & Field, 2008). Alternatively, the two types of biases may reflect two distinct, orthogonal aspects of threat-related information processing with distinct effects on individual differences in anxiety.

Recent experimental manipulations of attention and interpretative processes suggest that increasing an attention bias to threat and negative interpretive bias enhances an individual's vulnerability to stress (Eldar, Ricon, & Bar-Haim, 2008; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002; Mathews & Mackintosh, 2000; Mathews, Ridgeway, Cook, & Yiend, 2007). Thus, these cognitive biases likely contribute to both the development and maintenance of anxiety, where both biases may interact to increase an individual's vulnerability to anxiety (Hirsch, et al., 2006). However, to date, little research has examined the relation between cognitive biases and how they may interact and jointly contribute to the maintenance of anxiety.

Recently, several studies have provided initial evidence to suggest that a systematic change in one cognitive bias has significant effects on other cognitive biases (Amir, Bomyea, & Beard, 2010; Lange, et al., 2010; Salemink, Hertel, & Mackintosh, 2010). Salemink et al. (2010) found that interpretive bias training altered individuals' memories for interpretations made prior to training. Amir et al. (2010) illustrated a causal relation between interpretive bias training on attention bias to threat: anxious individuals that were trained to access the benign meaning of ambiguous information showed an improved ability to disengage their attention away from threatening information. However, it remains to be demonstrated whether induction of an attention bias to threat in non-anxious individuals affects how subsequent ambiguous information is interpreted. Since both an attention bias to threat and a negative interpretive bias are implicated in the development and maintenance of anxiety disorders, a causal impact of attention bias on interpretive bias may have important implications for the study of anxiety.

The current study assessed levels of attention bias to threat, interpretive bias, and stress vulnerability prior to an attention training procedure designed to induce attention bias to threat. Participants were then randomly assigned to one of two groups: for the training group, attention bias to threat was induced using a modified dot-probe paradigm (Eldar et al., 2008) where the target always appeared in the location of the previously viewed threat stimuli. In the control training group, the targets appeared during training with equal probability in the threat and neutral locations. After the training procedures, individuals in both groups were again assessed on their level of attention bias to threat, interpretive bias, and stress vulnerability. The current study tested whether undergoing the attention-training regimen would affect the manner in which subsequent ambiguous information was interpreted.

METHODS

Participants

Twenty-nine female young adult participants ($Mage = 20.80$, $SD = 1.35$) scoring within one standard deviation of the normal range on the trait section of the Spielberger State-Trait Anxiety Inventory (STAI-Y: Spielberger, Gorsuch, & Lushene, 1983) were recruited for this study. We selected only females based on the greater stress-reactivity profile in this sex (de Rivera, de las Cuevas, Monterrey, Rodriguez, & Gracia, 1993). Participants were randomly assigned to either the training or control condition. The mean STAI trait score did

not differ between the Control group ($M = 39.00$, $SD = 6.03$) and the Training group ($M = 41.73$, $SD = 4.23$), $t(27) = -1.42$, $p = 0.17$.

General Procedure—See Table 1 for outline of experimental procedures. After obtaining consent, participants were asked to complete a set of interpretive bias items. Participants were then given a set of mood scales to complete, followed by the first stress task (Block Design or Anagram Task) and a reassessment of the mood scales. Participants then completed a typical dot-probe task (100 trials) followed by assignment to one of two experimental groups: Training or Placebo Control. After training participants completed the second typical dot-probe task (100 trials) followed by a set of mood scales and a second set of interpretive bias items. Lastly, participants were given a second stress task, filling out the mood scales directly before and after the stress task.

At the end of the session, participants were briefed as to the purpose of the study and informed that both stress tasks were extremely difficult or unsolvable and that their performance was at no point videotaped during the experiment.

Measures

Attention Bias Measure: A Dot-Probe Task

Dot-probe Experimental Stimuli: The face stimuli consisted of 16 individuals (8 female, 8 male) taken from the NimStim Face Stimulus Set (MacArthur Research Network on Early Experience and Brain Development, 2002). Each face pair display consisted of an individual's angry and neutral facial expressions presented side-by-side. Each face was 11 cm tall by 8 cm wide, and the two facial expressions were presented at equal distance from the center of the screen. Eleven cm of white space separated the two face images. Probe arrows, oriented up or down, were 2 cm tall by 1 cm wide and presented in the center of the location previously occupied by one of the faces. A white fixation cross, 2.5 cm wide by 2.5 cm tall, was presented on the screen before the presentation of the faces. All stimuli were presented on a 17" monitor placed 0.5 m away from the participant. Fixation, face, and probe images were all .tif files created on a black background.

Dot-Probe Task Procedure: The dot-probe procedure consisted of three separate blocks, two test phases and one training phase. Each trial began with a fixation cross presented in the center of the screen for 500 ms, followed by the face display for 500 ms. After the face display presentation, an arrow, oriented up or down, appeared in the location of the previously viewed angry face (threat congruent trial) or neutral face (threat incongruent trial) for 200 ms. The arrow presentation was replaced by a blank screen in which the participants had up to 1400 ms to respond to the target orientation before the next trial began. Participants were asked to press one of two buttons on a button box as quickly and accurately as possible, to indicate the direction in which the arrow was pointing. The trial ended when a participant pressed a button or at the end of the response window. Location of the angry face, location of the probe, and orientation of the probe were balanced across trials. A 200 ms probe duration has successfully been used in previous studies (i.e., Barhaim et al., 2009) and was chosen in the current design to standardize probe displays across participants.

The pre-training and post-training blocks consisted of 100 trials each. The training session consisted of six blocks of 100 trials each (600 total training trials). Participants in the Training group only received threat congruent trials during training blocks. Participants in the Control group received an equal number of threat congruent and threat incongruent trials.

Interpretive Bias Measure: Sentence Completion Task—To assess participant's interpretive bias, forty-two questions from two previously established interpretive bias measures were adapted for the current study. Thirty sentences from the Sentence Completion Task (Huppert, Pasupuleti, Roa, & Mathews, 2007) and 12 non-social ambiguous scenarios from the Body Sensation Questionnaire (Clark, et al., 1997) were modified for paper administration. All sentences described ambiguous situations in which the last word or short phrase would disambiguate each situation. The sentences were presented to the participants with the last word or phrase omitted, and participants were told to complete each sentence with as many one-word or short phrases that came to mind in the order that they thought of them (e.g., "Your boss asks to talk to you because you are going to be _____(fired/promoted)", "Your heart is beating quickly because you are _____(nervous/excited)"). Once participants had generated a list of all the words that came to mind, they were asked to circle the response they felt best completed the sentence. Half the sentences were randomly selected for presentation during the pre-training assessment and half were selected for presentation during the post-training assessment. The sentences used in the pre- and post-training assessments were counterbalanced across participants. When participants received the list of sentences they were told to not spend too much time on any one sentence, but a time limit for completion of the measures was not given for either assessment period.

All responses were coded by one of two research assistants blind to the study's hypotheses and participant status. Coding procedures for the items were taken from Huppert et al. (2007) and Clark et al. (1997), depending on which measure the item was taken (please see Huppert et al. (2007) and Clark et al. (1997) for a more detailed description of coding guidelines). Each response was assigned to one of the following valence categories: positive, neutral, anxiety related negative interpretations, non-anxiety related negative interpretations, or unclassifiable. Coding was not done on the word or phrase alone, but in the context of the sentence. Since the original Clark et al (1997) coding scheme did not include a positive coding category, to make the two coding guidelines more parallel, a positive category was added for the non-social items. Non-social item interpretations were categorized as positive if they reflected an optimistic or good explanation for the event (e.g., 'excited' from the non-social example above). From the 42 sentences a total of 5,719 responses were recorded and coded. After being trained, each coder coded a subset of 809 items for reliability and achieved 95% agreement on codes. The total number of responses that were categorized as unclassifiable was relatively low (5.7% of all responses for the social items and 1.6% of all responses for the non-social items).

Analogue Mood Scales—To assess changes in mood over the course of the experiment, anxiety and depression analogue mood scales were both administered 5 times throughout the task. Scales reflected those used in MacLeod et al. (2002), but were adapted for paper administration. A 15 cm line was divided into 30 equal partitions. The anxiety scale had terminal labels "relaxed" and "anxious" and the depression scale had the terminal labels "happy" and "depressed". Participants were asked to circle the mark on the scale that most accurately reflected their current mood state. Scores ranged from 1–30 where higher scores reflect a more anxious or depressed mood.

Stress Induction Tasks—Two types of stress induction tasks were used: *The Anagram Stress Task* and *The Block-Design Stress Task*. Before each stress task, participants were told that the task was part of a department wide initiative to assess the relation between academic performance and cognitive tasks. Additionally, they were told that a link had been established between intelligence and the ability to solve anagrams/puzzles. Participants were also told that their performance would be videotaped and although it was not likely, if their scores fell within the top or bottom 10% they would be asked for permission at the end of

the experiment to use their video for teaching purposes in first-year psychology lab classes. The order of stress tasks was counter balanced across participants.

Anagram Stress Task: The anagram task was adapted from MacLeod et al. (2002) to create a stressful situation in which to elicit a negative mood state. Participants were told to unscramble a string of letters to make a word and write down the correct answer on a response sheet (provided by the experimenter). Once an anagram was completed participants were told to press a button on a response box to advance to the next anagram. Participants were told that if they could not solve an anagram they may press a button to skip ahead to the next anagram. Both the need for speed and accuracy in the task was emphasized to all participants. Before the experimenter started the timer and left the room, she walked over to the video camera to ensure the camera was pointing toward the participant and pretended to begin recording at that point.

Each anagram, a string of 5 cm letters, was presented in the center of a black screen in white font. After 3 minutes, the experimenter walked back to the room and gathered the response sheet from the participant. After examining the responses the experimenter informed the participant that their performance was unusually low and that she would like to use their video for later demonstration and that this would be discussed further at the end of the experiment. All anagrams were impossible or extremely difficult to solve.

Block-Design Stress Task: The block design task was adapted from a subset scale of the WAIS-III (Wechsler Adult Intelligence Scale, 1997) to create a stressful situation in which to elicit a negative mood state. Participants were given an assortment of red and white blocks and then shown a picture comprised of different orientations of these blocks. Participants were told to recreate as many picture designs as possible using the blocks provided. A similar timing and videotaping procedure to that used in the anagram task was also used for the block design task. Participants were told that their performance would be monitored by the experimenter in an adjacent room. Accuracy and speed were emphasized on the block design task. Participants were told once they had successfully completed one block design to move on to the next picture. Participants were also instructed that if they were unable to solve a specific block design that they may move on to the next design.

After 3 minutes, the experimenter walked back to the room and informed the participant that their performance was unusually low and that she would like to use their video for later demonstration and that this would be discussed further at the end of the experiment. All block designs were impossible to complete due to a missing block.

RESULTS

Attention Training

Dot-probe trials with incorrect responses, trials in which no response was given during the available 1400 ms response window, and reaction times (RT) less than 200 ms after target presentation were excluded from further analyses. In addition, within each block, RTs above and below two standard deviations of the mean RT for each subject in a specific experimental condition (threat congruent, threat incongruent) were excluded from the mean reaction time calculations for each participant. Individual's reaction time data points on pre- and post-training blocks and overall accuracy rates were examined for significant outliers. One participant was removed due to their outlier status on their reaction times during the pre-attention bias assessment. Three outliers were removed due to extremely poor task performance.

Overall accuracy rates on the dot-probe task ranged from 82%–94%. Pre- and post-attention training accuracy data was subjected to a Repeated Measures Analyses of Variance (RM-ANOVA) with Time (Pre-Training, Post-Training) and Trial Type (Threat Congruent, Threat Incongruent) as within-subjects factors and Group (Training, No Training) as a between-subjects factor to test for possible differences in accuracy. Results revealed that groups did not differ on their overall accuracy rate, $F(1,23) < 1$. There was a main effect of Time, $F(1,23) = 4.46, p = .05$, which was qualified by a significant Group X Time interaction, $F(1,23) = 4.13, p = .05$. Follow-up analyses revealed that the groups did not differ at pre-, $t(23) = -1.31, p = .20$, or post-training, $t(23) = 1.66, p = .11$, assessment points. However, while the Training group did not change in accuracy levels over time, $F(1,11) < 1$, the Control group showed significant improvement in their accuracy rate over time, $F(1,12) = 16.85, p = .001$.

To calculate bias scores, mean RTs on threat congruent trials were subtracted from mean RTs of threat 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. To examine changes in attention bias as a result of the attention training procedure, attention bias data were subjected to a RM-ANOVA with Time (Pre-Training, Post-Training) as the within-subjects factor and Group (Training, No Training) as a between-subjects factor. To probe significant interactions between Time and Group, separate RM-ANOVAs were conducted within each group to examine changes in pre- and post-training bias scores.

Mean RTs and standard deviations by trial type, bias scores, and change in bias scores are shown in Table 2. The RM-ANOVA revealed no significant main effect of Group, $F(1, 23) = 2.16, p = .16$, but there was a significant effect of Time, $F(1, 23) = 6.36, p = .02$. However, this main effect was qualified by a significant interaction between Time x Group, $F(1, 23) = 4.60, p = .04$. Follow-up analyses revealed that the Training group significantly changed their bias scores from pre- to post-training (bias change = 30.41 ms, $SD = 33.45$; $F(1, 11) = 9.92, p = .01$), no such change was detected in the Control group (bias change = 2.46 ms, $SD = 31.71$; $F(1, 12) < 1$). However, it should be noted that while the groups did differ over time as a function of training condition, post hoc t-tests revealed that the groups did not differ on bias scores after training, $t(23) = 0.03, p = .98$. In addition, despite participants being randomly assigned to a training condition, the groups did differ on their pre-training bias scores, $t(23) = 1.17, p = .04$. However, despite the initial bias away from threat in the Training group, the attention training procedure significantly altered attention bias in the Training group.

Effects of Attention Training on Interpretation Bias

Given differences in number of items for social and non-social scenarios, percentage scores were computed for each valence response category (anxiety related negative, non-anxiety related negative, positive, and neutral) separately for each scenario type. These scores were computed to reflect the proportion of each valence type of interpretation given relative to the total number of responses given by each participant. Due to a failure of many participants to circle a response they felt best completed each sentence, endorsed data were not analyzed in the current study.

To examine if the attention bias training procedure affected how ambiguous scenarios were interpreted, percent of first generated responses and percent of total given responses were separately subjected to a RM-ANOVA with Time (Pre-Training, Post-Training), Valence Category (Anxiety Related Negative, Non-Anxiety Related Negative, Positive, and Neutral), and Scenario Type (Social, Non-Social) as within-subjects factors and Group (Training, No Training) as a between-subjects factor. To control for possible differences in the items

included in the two interpretive bias questionnaire booklets, the order in which the booklets were given was entered as a covariate.

To directly test the current study's hypotheses significant interactions were probed by conducting follow-up RM-ANOVAs separately within each valence category (Negative, Positive, and Neutral), to examine the influence that the training procedure had on the generation of particular types of interpretations. For negative interpretations, Type of Negative Response (Anxiety Related Negative Interpretations, Non-Anxiety Related Negative Interpretations) was entered as an additional within-subjects factor. To correct for inflation of Type 1 error, these follow-up ANOVAs were conducted using a Bonferroni adjusted alpha of .0167 (.05/3). The separate ANOVAs for negative and positive interpretations tested the hypotheses that the attention training procedure increased negative interpretations and decreased positive interpretations. Although we did not have any a priori hypotheses regarding changes in neutral interpretations over time, these data were also subjected to an exploratory RM-ANOVA to examine if neutral interpretations changed as a function of training condition. To probe significant interactions between Time and Group RM-ANOVAs were ran separately within each group to examine change as a result of training.

Descriptive statistics for percent of first generated responses and total responses for each category are provided in Table 3.

First Generated Responses—To examine if the first generated interpretations given by participants differed as a function of the attention training procedure and the type of interpretations given (valence category) an overall omnibus ANOVA was conducted. Mauchly's tests indicated that assumptions of sphericity had been violated, Valence Category: $\chi^2(5) = 20.24, p = .001$; Time x Valence Category: $\chi^2(5) = 21.94, p = .001$; Valence Category x Scenario Type: $\chi^2(5) = 10.15, p = .07$; Time x Valence Category x Scenario Type: $\chi^2(5) = 22.42, p < .001$. Therefore, multivariate statistics are reported. Results revealed a significant main effect of Valence Category, Wilks' $\Lambda = .31, F(3,20) = 14.89, p < .001$, significant interactions of Time x Valence Category, Wilks' $\Lambda = .28, F(3,20) = 17.50, p < .001$, Valence Category x Scenario Type, Wilks' $\Lambda = .67, F(3,20) = 3.31, p = .04$, and Time x Valence Category x Scenario Type, Wilks' $\Lambda = .62, F(3,20) = 4.14, p = .02$. Of critical importance to the current hypotheses, the Group x Time x Valence Category interaction was significant, Wilks' $\Lambda = .68, F(3,20) = 3.21, p = .05$, indicating that the attention training procedure differentially influenced the likelihood of generating a given type (anxiety related negative, non-anxiety related negative, positive, and neutral) of first response. This did not vary as a function of scenario type; the Group x Time x Valence x Scenario Type interaction was not significant, Wilks' $\Lambda = .80, F(3,20) = 1.69, p = .20$. No other findings were significant.

First Generated Negative Responses—For the percent of first generated negative interpretations analysis, results revealed a significant main effect of Time, $F(1, 22) = 27.41, p < 0.001$, but the Group x Time interaction was not significant, $F(1, 22) < 1$. There was a significant interaction of Time x Negative Response Type, $F(1, 22) = 13.96, p = 0.001$ and the interaction of Time x Negative Response Type x Scenario Type interaction, $F(1, 22) = 5.33, p = 0.03$, was significant at trend level. The results revealed a significant Group x Time x Negative Response Type interaction, $F(1, 22) = 7.58, p = .01$, suggesting that the type of negative response first generated before and after the training procedure differed between the two groups. The Group x Time x Scenario Type, $F(1,22) = 3.08, p = .09$, and Group x Time x Negative Response Type x Scenario Type, $F(1,22) < 1$, interactions were not significant. No other findings were significant.

Follow-up analyses within the Non-Anxiety Related Negative Interpretations, revealed that neither the Control, $F(1,11) = 2.78, p = 0.12$, nor the Training group, $F(1,10) = 1.49, p = 0.25$, differed in their first generated general negative responses over time. However, individuals in the two groups did differ over time on their first generated anxiety related negative responses: individuals in the Training group significantly increased the number of first generated anxiety related responses after the training procedure, $F(1,10) = 77.63, p < .001$, while individuals in the Control group significantly decreased their number of anxiety responses over time, $F(1,11) = 18.05, p = .001$. In support of our hypothesis, the findings show that changes in first generated anxiety related negative responses differed as a function of the attention training procedure.

First Generated Positive Responses—Results examining changes in the percent of first generated positive responses revealed trend level effects of Time, $F(1, 22) = 4.00, p = 0.06$, Scenario Type, $F(1, 22) = 3.68, p = 0.07$, and Time x Scenario Type, $F(1, 22) = 4.00, p = 0.06$. Neither the Group x Time, $F(1, 22) = 2.17, p = 0.16$, nor Group x Time x Scenario type, $F(1, 22) = 2.17, p = 0.16$, interactions were significant. No other findings were significant. The current findings did not support the hypothesis that individuals in the attention training group would show a decrease in positive first generated interpretations.

First Generated Neutral Responses—Results examining changes in the percent of first generated neutral responses revealed a significant main effect of Time, $F(1, 22) = 28.95, p < 0.001$, where all individuals increased their level of neutral responses given over time. Neither the Group x Time, $F(1, 22) < 1$, nor Group x Time x Scenario type, $F(1, 22) = 1.28, p = .27$, interactions were significant. No other findings were significant.

Total Generated Responses—To examine if the total generated interpretations given by participants differed as a function of the attention training procedure and the type of interpretations given (valence category) the overall omnibus ANOVA was conducted. Mauchly's tests indicated that assumptions of sphericity had been violated, Valence Category: $\chi^2(5) = 18.96, p < .01$; Time x Valence Category: $\chi^2(5) = 15.36, p = .01$; Time x Valence Category x Scenario Type: $\chi^2(5) = 11.75, p = .04$. Therefore, multivariate statistics are reported. Results from the omnibus RM-ANOVA for percent of total interpretations revealed significant main effects of Time, Wilks' $\Lambda = .36, F(1,22) = 39.83, p < .001$, and Valence Category, Wilks' $\Lambda = .35, F(3,20) = 12.44, p < .001$, which were qualified by the interaction of Time x Valence Category, Wilks' $\Lambda = .19, F(3,20) = 28.89, p < .001$. There was also a significant interaction of Time X Scenario Type. Wilks' $\Lambda = .67, F(1,22) = 10.65, p < .01$, and a trend for Valence Category x Scenario Type Wilks' $\Lambda = .71, F(3,20) = 2.67, p = .08$. These two-way interactions were qualified by the three-way interaction of Time x Valence Category x Scenario Type, Wilks' $\Lambda = .33, F(3,20) = 13.36, p < .001$. However, this interaction was not qualified by training condition: neither the Group x Time x Valence Category, Wilks' $\Lambda = .96, F(3,20) < 1$, nor the Group x Time x Valence Category x Scenario Type, Wilks' $\Lambda = .99, F(3,20) < 1$, interactions were significant. The current findings do not support the hypothesis that the training procedure would differentially influence the type of total interpretations individuals generated when faced with ambiguous information. For this reason, follow-up analyses within valence type were not conducted.

Effects of Attention Training on Interpretation Bias: Mediation Analysis

To examine whether the level of change in attention bias mediated the previously found relation between the training regimen and change in anxiety related negative interpretations, a mediational analysis was conducted according to the procedures recommended by Baron and Kenny (1986). For a significant mediation model, these steps state that: 1) the predictor (training condition) should be significantly related to the outcome (change in anxiety-related

negative interpretive bias), 2) the predictor variable (training condition) must be significantly related to the mediator variable (change in attention bias), and 3) the mediator (change in attention bias to threat) significantly affects the outcome variable (change in anxiety-related negative interpretive bias) by causing a reduction in the relation between the predictor and outcome variables or showing complete mediation by reducing this relation to zero. When the current data were subjected to this series of steps, results revealed non-significant findings for the last step. In the current study, change in attention bias to threat did not mediate the link between training condition and change in anxiety-related negative interpretive bias. However, it should be noted that the current sample size was quite small to test a mediational model, and as such there was likely not enough power to detect any mediation effect (Frazier, Tix, & Barron, 2004).

Effects of Attention Training on Mood

Descriptive statistics for all mood scales are presented in Table 4. To examine if the attention training procedure directly affected changes in mood, anxiety and depression mood scales were subjected to separate RM-ANOVAs with Time (Pre-Training, Post-Training) as a within-subjects factor and Group (Training, No Training) as a between-subjects factor. Consistent with previous findings, no changes in anxiety or depression were detected directly after the attention training procedure, $F_s < 1.9$.

Effects of Attention Training on Stress Vulnerability

To examine if the attention training procedure was related to elevations in stress vulnerability, depression and anxiety scales were subjected to separate RM-ANOVAs with Time Relative to Training (Pre-Training, Post-Training) and Time Relative to Stress Exposure (Pre-Stressor, Post-Stressor) as within-subjects factors and Group (Training, No Training) as a between-subjects factor. To control for possible differences in the two types of stressors administered in the experiment, the order in which the stressors were administered was entered as a covariate. One participant was missing mood scale data prior to the post-training stress task and was removed from the analyses.

For the depression rating data, results revealed a significant main effect of Time Relative to Stress Exposure, $F(1, 21) = 6.07, p = .02$, in which all participants had higher depression ratings after stress exposure. However, the Group x Time Relative to Stress Exposure, $F(1, 21) = 2.64, p = .12$, and Group x Time Relative to Training, $F(1, 21) < 1$, interactions were not significant. The three-way interaction effects revealed that the attention training procedure did not increase an individual's vulnerability to depression during a mild stressor, $F(1, 21) = 2.00, p = .17$. No other findings were significant.

For the anxiety rating data, the results revealed a trend of Time Relative to Stress Exposure, $F(1, 21) = 3.23, p = .09$, where all participants tended to increase their anxiety after the stress task. Similar to the depression ratings, all the interaction effects with Group revealed that the attention training procedure did not increase an individual's vulnerability to anxiety during a mild stressor, $F_s(1, 21) < 1$. No other findings were significant.

DISCUSSION

The current study examined the relation between attention bias to threat and interpretive bias by manipulating individuals' attention bias to threat and assessing how this affected the interpretation of ambiguous information. The results suggest a relation between attention bias to threat and anxiety-related negative interpretive bias. Specifically, participants that underwent training designed to manipulate attention bias to threat displayed an increase in anxiety-related negative interpretations of ambiguous events. Although the total proportion

of anxiety-related negative interpretations did not differ between training and placebo attention groups, the first interpretation generated for ambiguous scenarios was more likely to be threat-related for individuals in the attention training group.

Preferentially allocating attention towards threat may cause a negative interpretive bias by highlighting otherwise disregarded or unnoticed threat-related information in the environment. As such, subsequent processing resources may favor threat-related interpretations. Thus, when individuals are faced with ambiguous information, an anxiety-related interpretation may be readily accessed when attention has been consistently directed to threat cues. This transfer between biases could be the result of a direct influence attention training had on attention bias and subsequently interpretive bias, or both attention and interpretive biases could be the product of a third, common processing mechanisms influenced by the attention training paradigm. While the current study cannot distinguish among different possible mechanisms that may link attention and interpretive biases, the findings do not support the notion that the two cognitive biases are orthogonal. Future research is needed in order to distinguish between the possible mechanisms that may link attention and interpretive biases.

The effects of attention bias to threat on interpretation appeared only when non-anxious participants accessed their first interpretation of an ambiguous scenario. When participants generated a list of all possible interpretations for each ambiguous scenario no group differences were found in the total types of interpretations. After participants provide an initial interpretation, it is likely that more elaborate and late stage processing is involved thus generating a list of multiple interpretations for a given scenario. While attention training may influence initial anxiety-related negative interpretations, more elaborate processing may override an initial threat-related interpretive bias.

We found an increase in anxiety-related negative interpretations, though no concomitant decrease in positive interpretations after the attention training procedure. Since non-anxious individuals often have a bias to interpret ambiguous information in a positive manner (C. Hirsch & Mathews, 1997), the current training procedure may not have been effective to override this bias. Moreover, the current results did not show effects for general non-anxiety related negative interpretations, but only for interpretations specific to anxiety related information. The specificity of findings in the current study may reflect a relation between the type of attention training and the type of interpretation affected.

While previous attention-training studies have shown that inducing an attention bias to threat increases an individual's vulnerability to stress (MacLeod, et al., 2002), the current study found no such training effects. This could be due in part to the nature of the attention training found in the "training" group. That is, although the training group showed a significant change in bias scores over time, this was a result of a reduction in their initial attention bias away from threat rather than an acquisition of an attention bias to threat. The lack of positive findings in this regard could also be the result of several methodological aspects of the current study. Prior work used both male and female subjects, while the current study examined exclusively female participants. As well, the current study used face stimuli in the dot-probe while MacLeod and colleagues (2002) used word stimuli and the current study also included a second type of stress task (the block design task).

The current results should be taken in light of several limitations. First, although subjects were initially randomized to training or placebo groups, due to chance, the two groups significantly differed in their attention bias scores at the pre-training assessment. Second, the attention procedure was not as successful as we had hoped it would be; after the training procedure the two groups did not differ on attention bias scores. However, despite these two

limitations, the significant 30.41 *ms* change in attention bias scores detected within the training group suggests that the attention training procedure was effective in altering the manner in which individuals attended threat. The lack of a significant attention bias to threat post-attention training demands that conclusions regarding change in interpretive bias as a function of the attention training procedure be viewed cautiously.

Finally, while the current study found a significant interaction between training condition and change in anxiety-related interpretations, mediation analysis failed to demonstrate that this interaction was directly due to the level of change in attention bias to threat. The sample size in the study may not have been large enough to generate the power needed to explore this meditational hypothesis.

Future work should also more specifically examine the temporal associations between attention bias to threat and negative interpretive bias. This could be accomplished through the use of electrophysiological techniques such as ERP (Event-Related Potentials, see Eldar & Bar-Haim, 2010; Helfinstein, White, Bar-Haim, & Fox, 2008). Additionally, this temporal association could be examined by inducing a negative interpretation bias and examining if this bias affects the way attention is allocated towards threatening information in the environment.

The current findings taken together with other recent findings and cognitive theories (Amir, et al., 2010; C. R. Hirsch, et al., 2006; Lange, et al., 2010; Salemin, et al., 2010), suggest that biases in attention and interpretation are intricately related. The current study provides initial results indicating that the manner in which attention is allocated towards threat-related information affects how ambiguous information is interpreted. Specifically, training non-anxious individuals to preferentially allocate their attention towards threat-related information in the environment increases the likelihood that these individuals will interpret ambiguous information in a threat-related manner. The current findings have significant implications for anxiety research, indicating that initial perturbations in information-processing associated with anxiety may lead to a cascade of subsequent processing biases.

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Table 1

Outline of General Procedure

Interpretive Bias (assessment 1)
Mood scale (set 1)
Stress Task (Anagram/Block Design)
Mood scale (set 2)
Attention Bias (assessment 1)
Attention Training
Attention Bias (assessment 2)
Mood Scales (set 3)
Interpretive Bias (assessment 2)
Mood Scales (set 4)
Stress Task (Anagram/Block Design)
Mood Scales (set 5)

Table 2

Attention Bias to Threat

	Control Group		Training Group	
	Mean <i>ms</i>	SD	Mean <i>ms</i>	SD
Pre-Training				
Bias Score	1.97	27.76	-26.26	36.92
Threat Congruent	651	89	640	109
Trial RT				
Threat Incongruent	649	101	614	93
Trial RT				
Post-Training				
Bias Score	4.43	26.62	4.15	24.15
Threat Congruent	541	87	585	141
Trial RT				
Threat Incongruent	544	85	589	142
Trial RT				
Bias Change	2.46	31.71	30.41	33.45

Note. Bias scores were calculated by subtracting the reaction times on trials in which the probe appeared in the location of the angry face from trials in which the probe appeared in the location of the neutral face. High scores represent an attention bias to allocate attention towards threat whereas negative scores indicate a bias to allocate attention away from threat.

Table 3

Interpretive Bias

	Control Group		Training Group	
	Mean	SE	Mean	SE
Social Scenarios				
<i>Anxiety Related</i>				
<i>Negative Responses</i>				
Pre-Training				
First	10.22	1.70	7.82	1.77
Total	10.24	1.54	8.93	1.60
Post-Training				
First	7.72	1.21	9.42	1.26
Total	9.42	1.22	9.16	1.27
<i>Non-Anxiety Related</i>				
<i>Negative Responses</i>				
Pre-Training				
First	26.69	4.12	37.76	4.29
Total	27.80	3.40	31.27	3.54
Post-Training				
First	29.01	4.50	25.40	4.69
Total	28.54	3.94	28.92	4.10
<i>Positive Responses</i>				
Pre-Training				
First	22.02	3.49	20.59	3.63
Total	19.76	3.29	21.93	3.43
Post-Training				
First	17.86	3.60	23.55	3.74
Total	19.23	2.76	21.20	2.87
<i>Neutral Responses</i>				
Pre-Training				
First	40.08	4.58	33.25	4.77
Total	38.77	4.01	34.98	4.17
Post-Training				
First	43.87	5.48	41.09	5.71
Total	39.80	4.16	38.62	4.33
<i>Unclassifiable Responses</i>				
Pre-Training				
First	.99	.63	.59	.66
Total	3.44	.63	2.89	.65
Post-Training				
First	1.54	.71	.55	.74

	Control Group		Training Group	
	Mean	SE	Mean	SE
Total	3.03	.56	2.10	.59
Non-Social Scenarios				
<i>Anxiety Related</i>				
<i>Negative Responses</i>				
Pre-Training				
First	20.54	3.74	12.47	3.90
Total	13.71	3.71	13.78	3.87
Post-Training				
First	11.77	4.33	17.80	4.51
Total	16.56	3.81	14.33	3.96
<i>Non-Anxiety Related</i>				
<i>Negative Responses</i>				
Pre-Training				
First	6.57	3.90	10.94	4.06
Total	15.85	3.83	19.43	3.98
Post-Training				
First	9.24	3.08	9.43	3.21
Total	12.69	3.03	14.46	3.16
<i>Positive Responses</i>				
Pre-Training				
First	-.09	0.92	1.49	0.96
Total	.42	.67	1.19	.70
Post-Training				
First	-0.9	.92	1.49	0.96
Total	.75	.56	.91	.58
<i>Neutral Responses</i>				
Pre-Training				
First	72.98	5.76	75.10	6.00
Total	69.62	4.30	64.61	4.48
Post-Training				
First	79.08	4.69	71.28	4.88
Total	69.63	3.63	69.02	3.78
<i>Unclassifiable Responses</i>				
Pre-Training				
First	.00	.00	.00	.00
Total	.40	.55	.98	.57
Post-Training				
First	.00	.00	.00	.00
Total	.37	.68	1.28	.71

Note. All means are percentiles controlling for the order in which the interpretive bias questionnaire booklets were administered.

Table 4

Stress Vulnerability

	Control Group		Training Group	
	Mean	SE	Mean	SE
Mood Scales Directly Before Training				
Depression Scale Pre-Training	15.14	1.98	15.72	2.06
Anxiety Scale Pre-Training	18.77	2.25	17.12	2.34
Mood Scales Directly After Training				
Depression Scale Post-Training	12.41	1.86	11.18	1.93
Anxiety Scale Post-Training	12.16	2.29	10.62	2.39
Pre-Training Stressor				
Depression Scale Pre-Stressor	8.25	1.31	6.67	1.31
Depression Scale Post-Stressor	15.58	2.08	15.71	2.08
Anxiety Scale Pre-Stressor	12.00	1.67	9.17	1.67
Anxiety Scale Post-Stressor	18.08	2.33	17.13	2.33
Post-Training Stressor				
Depression Scale Pre-Stressor	11.00	1.35	7.46	1.35
Depression Scale Post-Stressor	13.50	2.30	15.38	2.30
Anxiety Scale Pre-Stressor	11.50	2.18	9.54	2.18
Anxiety Scale Post-Stressor	15.42	2.14	12.67	2.14

Note. All means are controlling for the order in which the two types of stressors were administered.