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Inducing a benign interpretational bias reduces trait anxiety

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Abstract

If negative interpretational bias causes emotional vulnerability, reduction of this bias should reduce proneness to anxiety. High trait-anxious volunteers were trained over four sessions to resolve descriptions of ambiguous events in an increasingly positive manner. This group subsequently made more positive interpretations of novel descriptions than did those in a test–retest control condition. Furthermore, trait anxiety scores reduced more in the trained group than in untrained controls. These results confirm earlier findings that modifying interpretation biases produces congruent changes in emotional vulnerability, and suggest a possible role for similar training methods in controlling pathological anxiety.

Keywords: Anxiety; Cognitive bias; Interpretation; Modification

1. Introduction

It is now well established that those prone to negative emotional states are less likely than are other groups to interpret ambiguous events in a relatively positive manner (Eysenck, Mogg, May, Richards, & Mathews, 1991; Lawson, MacLeod, & Hammond, 2002). In the study reported by Eysenck et al. (1991), anxious patients and nonanxious controls first listened to sentences, some of which were ambiguous and could be interpreted

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in a more or less threatening manner (e.g., the doctor examined little Emma's growth). The way in which the critical sentences were understood was assessed by presenting a series of similar items in which the ambiguous meaning had been resolved in either a threatening or benign direction. In a later recognition test (e.g., by referring to Emma's tumor or her height), nonanxious participants were less likely to endorse threatening than benign meanings as matching the original sentence, whereas anxious patients endorsed the threatening interpretations as often as they did benign meanings.

Such findings suggest—but do not prove—that a (relatively) negative interpretational style could be a contributory cause of vulnerability to anxiety. However, it could be that the apparent associations arise because a preexisting state (or vulnerability) leads to less positive interpretations being made, rather than the other way around. Furthermore, both vulnerability and interpretation style could be independently produced by other processes, so that there might be no direct causal link between mood and interpretation.

More convincing evidence of a causal link between the two has been provided by recent studies in which interpretational biases were experimentally manipulated (Grey & Mathews, 2000; Mathews & Mackintosh, 2000; Yiend, Mackintosh, & Mathews, 2005; Wilson, MacLeod, Mathews, & Rutherford, 2006). In these studies, nonanxious volunteers were randomly allocated to conditions in which they made either negative or benign interpretations of ambiguous text. For example, Mathews and Mackintosh (2000) presented nonanxious volunteers with short texts describing ambiguously threatening social situations, with the emotional outcome being resolved only by the final word, which was presented in fragment form. Participants were required to complete this fragment, and then to answer a question designed to reinforce the designated emotional meaning. Those allocated to a condition in which outcomes were nearly always negative, were subsequently more likely to interpret new ambiguous descriptions in a similarly negative fashion than were those previously exposed to more benign outcomes. Importantly, anxious mood also changed congruently, but only in those who were trained under conditions requiring the active generation of meaning: that is, those who had to complete the resolving fragment and question. In other conditions, participants exposed to the same information—but who did not have to generate it for themselves—developed the same interpretative bias for new descriptions, but did not change in mood.

Thus, although active generation of emotional meanings during training can alter mood, such mood changes are not a necessary condition for the induction of interpretative bias. Some forms of training produced interpretation biases even in the absence of mood change. To further illustrate this point, consider the results reported by Wilson et al. (2006). The training used in this study was based on that developed by Grey and Mathews (2000), in which volunteers were presented with homograph primes having both threatening and benign meanings, followed by a word fragment to complete corresponding to one of these meanings (e.g., the homograph "sink" followed by fragments corresponding to either "drown" or "basin"). No mood change was observed during training, even after prolonged practice with either threatening or benign completions. Despite this, tests with new homographs revealed that a differential interpretative bias had indeed been induced. Participants then viewed a series of videos of real-life accidents and the group assigned to prior practice with threat completions reported greater increases in anxiety than did a comparison group that had practiced benign completions. Thus an interpretative bias can be induced experimentally without necessarily changing mood at

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the time, but changes in emotional vulnerability can be observed if the induced bias influences how potentially emotional events are processed.

Although these findings provide evidence that induced negative interpretative style can increase vulnerability to anxiety, they do not demonstrate that pre-existing vulnerability to anxiety can be reduced by similar methods. The designs used have involved the comparison of groups assigned to either threatening or benign training, so it remains unclear whether differences were mainly due to negative changes occurring in those trained in the threat condition, rather than to positive effects due to benign training. Furthermore, participants with elevated negative emotionality scores were generally excluded from these studies for ethical (and other) reasons, so little can be concluded about changes in such vulnerable groups.

Encouraging results with high trait anxious individuals have been obtained, however, in parallel work carried out using a method developed by McLeod and colleagues to train attention towards or away from threat cues (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002. Student participants saw two words displayed simultaneously, one threatening and one benign, followed by a to-be-responded-to target in the location of one of the words. In one group the target was nearly always in the location of the threatening word (attend-threat training), while in the other group the target was in the benign location (avoid-threat training). Once again no differential emotional changes were observed during training, but differences did emerge when a post-training stressful task was performed, with more anxiety elevation in the attend-threat group. More critically for current purposes, subsequent studies involving highly anxious students showed that repeated sessions of avoid-threat training led to greater reductions in anxiety than did a neutral control condition (for more details see Mathews & MacLeod, 2002).

Although we (Mathews & Mackintosh, 1998) had proposed that both biased attention to threat and biased interpretation favoring threatening meanings could arise through similar underlying processes, in preliminary unpublished studies we have found little evidence that the two types of bias are correlated within nonclinical populations. Perhaps both types of bias can independently enhance emotional vulnerability but without having reciprocal influences on each other. In any event, at this stage we would not want to predict that induction of one type of bias would necessarily produce consistent effects on others. None the less, if reduction of a bias to attend towards threat in anxiety-prone individuals reduces vulnerability, then the assumption that interpretative bias also has a causal role in anxiety suggests that training designed to induce more positive interpretations should also have beneficial effects.

In order to test this possibility, we re-designed the training material originally developed by Mathews and Mackintosh (2000). This original material consisted of a series of about 100 descriptions of ambiguous social events that participants were to read and imagine, and which could be resolved in either a benign or negative manner. In pilot work we redesigned this material so that the ambiguous events previously resolved in a negative or benign manner were now concluded more positively. Additional training items involving ambiguous physical threats were added to the prior social descriptions so as to expand the total number to 200, allowing 50 to be used in each of four sessions. Finally, a matched set of supposedly neutral control descriptions were developed, from which we attempted to remove explicitly emotional wording.

In a pilot study of high anxious volunteers allocated at random to four sessions of positive or neutral training, we found some differences in final anxiety scores favoring the

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positive group. However, inspection of actual mean scores revealed that the difference was almost entirely due to paradoxical increases in anxiety in the control group, with little or no improvement in the positive group. In retrospect, we concluded that removal of explicit emotional references was not sufficient to prevent threatening interpretations about inherently ambiguous situations, particularly in highly anxious populations. To clarify this point, in order to match the ambiguous training content, control descriptions included events such as meeting new acquaintances, or walking in town alone. Including this content may have allowed spontaneous threatening interpretations, but (unlike positive training) the ambiguity cannot be resolved positively (to avoid training effects), nor can it be resolved negatively (for several reasons including ethical considerations). On the other hand, substituting completely different neutral content would not control for the effects of repeated exposure to similar material. Seeing no obvious solution to this dilemma, in the present study we decided to first compare a revised positive training condition with a test–retest control group who did not receive any training, which at least avoided the risk of inadvertently increasing anxiety. Of course, the corresponding disadvantage is that any positive results could be attributed to exposure to materials and the test situation in the trained group, although our experience of unexpected negative consequences following such exposure suggests this is unlikely.

In thinking about why positive training effects were not more apparent, we noted that some participants reported finding it difficult to identify themselves with the very positive event outcomes described in training, and a few even reported being irritated by having to endorse such (for them) unrealistic interpretations. This suggested the possibility that it would be more effective to introduce positive outcomes in a more graded fashion, beginning as nonnegative and gradually becoming explicitly positive.

2. Method

2.1. Design

Forty high anxious volunteers (scoring more than 40 on the trait scale of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) were recruited and randomly allocated to four sessions of positive training over a two-week period, or to a test–retest control condition. In both groups, the study was described as an experiment that required repeated attendance, but without any mention of possible benefits or the selection criteria used. In addition to the STAI questionnaire, we assessed initial interpretative bias, and repeated this assessment two weeks later. Trait anxiety was assessed again in both groups after a further week follow up, using forms completed at home and returned by mail.

2.2. Training material

Given the problems encountered with acceptance of positive items in the pilot study described above, the training material was further modified so as to introduce positive interpretations in a more graded fashion. Each of 100 basic descriptions was first presented in a form requiring participants to reject a possible negative interpretation, rather than to endorse a definitely positive meaning (for evidence supporting this method, see Alden & Wallace, 1995). After reading each description on the screen, participants answered a

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question designed to elicit the required response, by pressing one of two keys on the computer. For example, one item (usually presented in the first training session) read as follows:

> At your word processing lesson you finish your work early and the lecturer gives you a new task to do. You don't understand the new task and ask for advice. The lecturer says that asking for help is not a sign of incompetence.
> What was your lecturer's attitude towards your request for help?
> (a) understanding or (b) wishful

The required response (underlined here, but not when actually presented) was the only realistically meaningful alternative presented, thus virtually ensuring its selection (failures to do so were followed by an "incorrect" feedback message).

In the second version of this item (usually presented on second attendance) the first two sentences were presented in similar form, although with some inconsequential changes of wording to avoid exact repetition, and with the final sentence changed to express a somewhat more positive resolution. An appropriately modified question requiring a mildly positive interpretation was then presented (see below).

> At your new computer class you have finished the assigned task and the lecturer gives you a new assignment to work on. You don't understand what to do and ask for advice.
> The lecturer says that your request is reasonable.
> What was your lecturer's attitude towards your request for help?
> (a) beautiful or (b) helpful

In the third version (usually seen in session three) a similarly worded version concluded in a more definitely positive fashion, as follows:

> The lecturer says that your request is a sign of competence.
> What was your lecturer's attitude towards your request for help?
> (a) encouraging or (b) loving

In the fourth version of an item, the outcome was left ambiguous and both possible responses to the question following were meaningful, but with one being clearly positive and the other clearly negative. The intent here was to allow participants to endorse a positive interpretation and to reject a possible negative interpretation, but without being forced to do so. Consequently, no "incorrect" feedback was given regardless of the answer (in practice the number of negative responses made were very few). The final sentence and corresponding question in this version of the current example (usually seen in session four) thus read as follows:

> As they assist you, you are aware of your lecturer's opinion.
> What was your lecturer's attitude towards your request for help?
> (a) furious or (b) approving

In general, different versions were presented in the graded order shown above across successive sessions, so that version 1 was presented in session 1, version 2 in session 2, and so on. However, in order to make the exact form of items less predictable, this applied only to 80 of the 100 descriptions in each session, with the other 20 items being a mixture of versions worded in each of the alternative ways described above.

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2.3. Measures of interpretative bias

2.3.1. Reasons for ambiguous events

This test was loosely based on a measure of subjective risk first developed by Butler and Mathews (1983). A series of ten new unexplained events were presented and participants invited to think about the most likely reason for each event. For example, one item began as follows:

(6) Not long after starting a new job your boss asks to see you. Why?

After participants had been given a moment to think about possible reasons, they were offered three specific explanations and asked to place them in rank order according to how likely they would be to come to mind. These explanations were designed to be emotionally neutral, negative or positive and were presented in random sequence (see example below).

(a) Your boss wants to make sure you have settled in all right (neutral).
(b) You haven't been doing your job properly (negative).
(c) Your boss is going to tell you how well you have been doing (positive).

2.3.2. Imagined ambiguous events

In this measure of bias, developed from the recognition task used by Mathews and Mackintosh (2000), participants were presented with novel descriptions of ten ambiguous situations, each having possible negative or positive outcomes, and asked to get a clear mental image how each might turn out. Different items were presented on each occasion of testing, and none overlapped with any used in training. An example description follows.

(5) Some important people are visiting your office and you are asked to present a project to them. On the day, you arrange your slides, aware of the fact that a lot depends on your presentation.

After participants had indicated that they had an image of the outcome, four possible outcomes were presented in random order, ranging from very positive to very negative, and participants were asked to rate each alternative for its similarity to their image, on a four-point scale from very different (1) to very similar (4). Participants were encouraged to rate each alternative independently rather than selecting one and rejecting all others. The four offered outcomes corresponding to the above example were as follows:

(a) Your talk goes very well and the visitors are impressed (very positive).
(b) Your talk was reasonable and the visitors were attentive (positive).
(c) You are dissatisfied with your talk and could have done better (negative).
(d) Your talk was very poor and you are very concerned about it (very negative).

2.4. Participant recruitment

Community members of the panel, maintained by the MRC Cognition and Brain Sciences Unit of participants who regularly participate in experiments at the Unit, were contacted by telephone if their prior records suggested elevated scores on measures of anxiety. Participants were asked if they would be willing to take part in a study that could involve two or four attendances over a two-week period. No mention was made of the

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reasons for their selection, and the study was described only as an experiment on understanding verbal information that would be presented by computer. Those who agreed were first administered the trait anxiety scale of the STAI (Spielberger et al., 1983), and only those whose scores were greater than 40 were included in the present study. Those not meeting this criterion proceeded immediately to an alternative experiment. This selection process continued until 40 participants had been recruited, 20 being randomly allocated to each condition, with minor departures from random allocation only as necessary to ensure a balance in gender and anxiety levels across groups. One participant was subsequently removed from the positive training group when it transpired that she was simultaneously taking part in another experiment that involved repeatedly viewing anxiety-inducing videos.

2.5. Procedure

After recruitment as described above, including the administration of the STAI trait form, informed consent was obtained, with the study being described as an investigation of the ease of understanding verbally described situations, that could vary in how pleasant or unpleasant they were. The use of the anxiety questionnaire was explained as a check on the possibility that verbal comprehension could be related to mood. All participants were then administered the two measures of interpretative bias. Those allocated to the control group were then asked to return in two-weeks time for the second part of the experiment.

Those allocated to the positive practice group continued directly to the first training session, which lasted about 45 min. All training material was presented by computer in self-paced fashion, with successive lines of text appearing as participants pressed an 'advance' key. They were encouraged to imagine themselves as the central character in each description, irrespective of whether they thought such a situation could ever actually occur to them. Answers to the question presented after each description were recorded using a key press response indicating which of the two single word alternatives offered was most appropriate in that context. Three subsequent appointments were then arranged with the participant, spread as evenly as possible over the next two weeks. The fourth and final training session was immediately followed by re-administration of the two tests of interpretation bias, using a new set of items, with sets used at test and re-test balanced over participants within groups.

Participants allocated to the control condition also returned after two weeks, and repeated the same two tests of interpretative bias. All participants were then given dated envelopes containing STAI trait forms, together with instructions to complete the form inside on the given date (one week later) and to return it in the stamped and addressed envelope provided. The few participants who failed to return the forms on time were telephoned shortly after the scheduled date and prompted to do so.

The re-test of trait anxiety level was delayed for one week for two reasons. First, we supposed that changes in emotional responsiveness due to training might be apparent only after any induced interpretative biases had influenced how real-life events were processed. Second, the instructions given to participants for completing the trait scale relate to feelings in general, requiring the estimation of emotional experience over time, so a reasonable period of time after training was needed for any changes to be noted.

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3. Results

3.1. Participant characteristics

The final groups were well balanced for gender, with 13 women and 6 men in the positive training group, and 14 women and 6 men in the control group. Similarly, there were no significant differences in mean age between the groups (41.9, s.d.15.5 vs. 39.4, s.d. 16.2), or initial trait anxiety scores (see Table 1 for means).

3.2. Changes in interpretation bias measures

3.2.1. Reasons for ambiguous events

In this test participants placed positive, neutral and negative reasons for an unexplained ambiguous event in rank order. Reasons ranked first were assigned a score of 3, reasons ranked second a score of 2, and those ranked last were assigned a score of 1. Average scores were then computed separately for positive and negative reasons, but since these scores completely constrained the ratings of neutral items the latter were not analyzed. Furthermore, ranks given to negative and positive reasons were themselves negatively correlated (at time 1, $r\ (37) = -0.81$, $p < 0.01$) and initial scores were correlated with time 2 scores (for negative items $r\ (37) = 0.84$, positive $r\ (37) = 0.65$, $p < 0.01$). For these reasons, we carried out an analysis of covariance on ranking scores given to positive items at time 2, with analogous scores at time 1 being used as the covariate. Positive means at time 2 were higher in the trained than the control group, $F\ (1,34) = 6.68$, $p < 0.02$, $\eta^2 = 0.16$ (missing data on two participants reduced the degrees of freedom in this and the following analysis). Conversely, negative items were ranked lower by the same group, $F\ (1, 34) = 9.64$, $p < 0.01$, $\eta^2 = 0.22$ (see Table 1 for means). Although we chose to use analysis of covariance in order to control for the strong influence of initial scores, results of repeated measure analyses of variance were similar. Positive items were ranked higher at time 2 in the trained group but did not increase over time in the control group, group by time interaction $F\ (1, 35) = 5.15$, $p < 0.03$, $\eta^2 = 0.13$. Conversely, negative items were ranked lower only in the trained group, $F\ (1, 35) = 5.46$, $p < 0.03$, $\eta^2 = 0.16$.

Table 1
Means (and standard deviations) of interpretative and anxiety measures for each group on each occasion of testing

	Positive trained group		Test–retest control group	
	Pre	Post	Pre	Post
Imagined events				
Negative	2.15 (0.37)	1.93 (0.34)	2.39 (0.47)	2.29 (0.40)
Positive	2.45 (0.37)	2.98 (0.37)	2.35 (0.34)	2.63 (0.37)
Reasons for events				
Negative	1.70 (0.48)	1.54 (0.41)	1.91 (0.37)	1.92 (0.37)
Positive	1.86 (0.31)	1.95 (0.32)	1.84 (0.26)	1.76 (0.23)
State anxiety	36.3 (8.8)	34.0 (8.9)	37.4 (10.3)	37.8 (8.4)
Trait anxiety	49.2 (6.8)	45.6 (5.6)	50.5 (7.0)	49.9 (7.9)

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3.2.2. Imagined ambiguous events

Scores were created by averaging the 1–4 ratings of similarity for each participant's images, separately for the positive and negative alternatives offered. Inspection and preliminary analysis of the data revealed little indication of any systematic differences between the ratings given to the positive versus very-positive alternatives, or between the negative versus very-negative alternatives. To simplify analysis, therefore, we computed an average similarity score for all positive and all negative alternatives for each participant, on each occasion of testing. As before, initial positive and negative means were negatively correlated, $r\,(39) = -0.51$, and initial scores were positively correlated with corresponding scores at time 2 (0.59 and 0.55). Mean scores for positive (and negative) items at second testing were thus entered into analyses of covariance as before, with initial score as the covariate.

Analysis of positive ratings revealed a significant difference between groups at time 2, $F\,(1, 36) = 8.77$, $p < 0.01$, $\eta^2 = 0.20$, with higher means in the trained group. Conversely, means for negative items were lower in the same group, $F\,(1, 36) = 5.66$, $p < 0.03$, $\eta^2 = 0.14$ (see Table 1). Repeated measure analyses of variance for positive items revealed general increases that were greater in the trained group, group by time $F\,(1, 37) = 5.79$, $p < 0.03$, $\eta^2 = 0.14$. Both groups showed mean decreases in negative ratings that did not differ significantly, $F\,(1, 37) = 0.93$ (results reported as nonsignificant refer to p values of more than 0.10, those reported as trends refer to values between 0.10 and 0.05).

Thus, in both tests of interpretation bias, each with a different task format and using materials not previously presented, positive training increased the perceived likelihood of positive explanations for ambiguous events and enhanced positive images of outcome. Similarly, training decreased perceived likelihood of negative explanations and (when initial levels were statistically controlled) reduced negative images. Together, these findings indicate that training had the desired effect of enhancing access to positive mental representations of ambiguous events and decreasing access to negative representations of these events.

3.3. Changes in anxiety

As noted earlier, STAI anxiety scores were collected at recruitment into the study; state anxiety was sampled at the time of re-testing interpretative bias and trait anxiety was assessed one week later. This delay of one week after the final training/assessment session was intended as the critical test of whether the effects of modifying interpretation bias led to relatively enduring changes in general vulnerability to anxiety. As with the measures of interpretation bias, both state and trait scores at baseline were correlated with final scores at follow up, $r\,(39) = 0.63$ and 0.67, $p < 0.01$. State anxiety means declined slightly over time but there were no significant differences on analysis of covariance, $F\,(1, 37) = 1.02$, nor any significant effects on repeated measure analysis of variance, $F\,(1, 38) = 0.43$.

More importantly, final trait anxiety scores differed significantly between groups when baseline levels were controlled in analysis of covariance, $F\,(1, 36) = 4.25$, $p < 0.05$ $\eta^2 = 0.11$. This was attributable to lower trait scores in the trained group compared to the control group. On repeated measure analysis of variance, despite a trend in the same direction, the group by time interaction did not reach significance, $F\,(1, 37) = 2.82$, $p = 0.10$, $\eta^2 = 0.07$. Changes in trait anxiety were not significantly correlated with changes in either of the two measures of interpretative bias with correlations ranging

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between $r\ (39) = 0.12$ (for reduction in trait anxiety with decrease in negative image similarity ratings) to $r\ (39) = -0.13$ (for trait reduction with decrease in positive image ratings).

4. Discussion

The main finding of the present study was that it proved possible to modify interpretation biases in relatively anxious participants, consistent with expectations from previous findings (Mathews & MacLeod, 2002). That is, participants selected as having trait anxiety scores above 40, who received four sessions of graded training designed to influence interpretative biases in a more positive direction, showed more change than did nontrained controls on two measures of interpretative bias involving novel material and presented within a different format to that used in training. Although the tests used thus differed from prior training in several ways, it remains possible that the changes induced were confined to interpretative responses made to related verbal material and would not generalize to real-life events, nor to other processing biases. Further research is required to investigate these important questions. Nonetheless, the present results are encouraging in that they indicate that modified versions of existing methods of training can indeed bring about some changes in participants selected as being prone to relatively high levels of anxiety.

Achieving such a change is by no means a foregone conclusion, and indeed our first such attempt (described in the Introduction) did not show a clear training effect. The present method was developed in response to adverse comments made by some of these earlier participants. In contrast, few if any of the present participants reported that the responses required were inappropriate or incompatible with their own feelings, suggesting that the change to a more graded method of introducing positive interpretations may have been effective in avoiding the tendency for highly anxious individuals to reject them as unrealistic. If so, the present finding may have implications for modifying pathological emotional states.

The present study was not designed to investigate the mechanism of change in training, although in prior work (Mathews & Mackintosh, 2000) we have considered several possible explanations, including demand or mood effects, priming of a general category of emotional meaning, and acquisition of an implicit production rule (e.g., the covert equivalent of "if two or more meanings are possible then select the more positive"). Our earlier results suggested that both long-term priming and implicit rule learning play a role in this induction method, and may thus apply equally to the changes seen here. Mood induction directly due to the training procedure can occur but we have previously shown that interpretative training effects are similar with or without mood changes, consistent with the lack of significant state changes in the present study at the time interpretative bias was reassessed.

Similarly, on the basis of previous evidence, we suggest that demand effects are unlikely to provide a sufficient explanation. In previous research, the use of standard probe trials has revealed that decision latencies for training-congruent decision latencies are speeded while incongruent latencies are slowed, so that training effects are not confined to self-report measures (Mathews & Mackintosh, 2000). Furthermore, very few participants could guess correctly the purpose of the experiment when interrogated later. Similarly, in the present experiment, presenting the whole procedure as a standard experiment of the sort to which these volunteers were accustomed probably prevented any expectations of benefit.

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Consistent with this, debriefing participants after training gave no indications that they believed that any changes were expected. The few comments made suggested that if any changes did occur, participants were surprised by them or attributed them to other factors. For example, one participant incidentally commented that she was surprised to find that she felt less nervous than usual when alone at home after returning from a positive training session. While such anecdotal reports do not constitute reliable evidence, nonetheless they led us to believe that most—if not all—participants who reported changes were not doing so just because they felt it was expected of them. Demand explanations must always remain a possibility when self-report measures are used, but in the light of previous findings and the current participants comments seem to us unlikely to provide a sufficient explanation.

The other important finding was that trait anxiety scores were reduced more in the positive trained group than in the control group not receiving training, significantly so when baseline levels were statistically controlled. We had predicted such a reduction, based on the hypothesis that interpretative bias may play a causal role in elevating vulnerability to anxiety by influencing how real-life ambiguous events are interpreted. Changes of bias in a more positive direction, as was found here, should thus reduce vulnerability. However, it is not possible to know if this was indeed the causal mechanism, and no supporting evidence was found in the form of correlations between interpretative bias and trait anxiety change. Perhaps our measures of interpretative bias were poor predictors of real-life responses, or perhaps trait changes are observed after training only when real (and randomly occurring) ambiguous events provide the opportunity for the modified interpretative bias to influence vulnerability to anxiety.

Alternatively, the changes in interpretative bias and anxiety reduction seen in the positive training group may be attributed to some other influence, such as repeated exposure to ambiguously threatening descriptions, or some other nonspecific features of repeated experimental contacts. As indicated earlier, we do not think such alternative explanations are likely, because our first study utilized a control procedure that did involve such repeated exposure to ambiguous descriptions, and repeated contact with the experimental situation, but resulted in no improvement in interpretative bias and a trend for anxiety to increase rather than decrease. Thus it seems unlikely to us that exposure per se (or perceived demand) accounts for the decreases seen here in the positive training group. None the less, in future research it will be important to develop more emotionally neutral control procedures that can be compared with positive training, as well as providing more explicit tests of the putative mechanisms underlying reductions in vulnerability to anxiety.

A final remaining caveat is that the actual changes seen in trait anxiety were relatively small and evidence for reduced vulnerability to anxiety was limited to self-report. Future research could profitably employ additional and more objective measures of emotionality, such as psychophysiological or neuroimaging studies of response to ambiguous threats. Furthermore, although effects were detected one week after the end of training it is not known how long they actually endured. Clearly, it is important, first, to replicate the present findings before they can be considered reliable, and second, to investigate if larger and longer lasting effects can be achieved with more extensive practice across a wider range of events, when assessed by multiple measures. Despite these reservations, the present results seem encouraging and suggest that further research along similar lines is likely to have important implications for the development of alternative treatment methods having the advantage of being deliverable by computer and via the internet.

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