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How Does Cognitive Bias Modification Affect Anxiety? Mediation Analyses and Experimental Data

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Background: There is overwhelming evidence that anxiety is associated with the tendency to interpret information negatively. The causal relationship between this interpretive bias and anxiety has been examined by modifying interpretive bias and examining effects on anxiety. A crucial assumption is that the effect of the procedure on anxiety is mediated by change in interpretive bias rather than being a direct effect of the procedure. Surprisingly, this had not previously been tested. **Aim:** The aim is to test whether altered interpretive bias, following Cognitive Bias Modification of Interpretations (CBM-I), affected anxiety. **Method:** Mediational path analyses were conducted to test the hypothesis that changes in anxiety are due to changes in interpretive bias. A separate experiment was conducted to test which elements of the procedure could be responsible for a direct mood effect. **Results:** Results from mediation analyses suggested that changes in trait anxiety, after performing CBM-I, were indeed caused by an altered interpretive bias, whilst changes in state anxiety appear to be caused by the procedure itself. The subsequent experiment showed that state anxiety effects could be due to exposure to valenced materials. **Conclusions:** Changed state anxiety observed after CBM-I is not a valid indicator of a causal relationship. The finding that CBM-I affected interpretive bias, which in turn affected trait anxiety, supports the assumption of a causal relationship between interpretive bias and trait anxiety. This is promising in light of possible clinical implications.

Keywords: Anxiety, Cognitive Bias Modification, interpretive bias.

Background

Cognitive models of anxiety propose that the tendency to interpret ambiguous information as threatening plays a causal role in the aetiology and maintenance of pathologic anxiety (Beck and Clark, 1988). There is overwhelming evidence that such biased interpretations and anxiety are associated, yet the causal direction remains unclear. Mathews and Mackintosh (2000) examined this issue of causality by inducing a negative or positive interpretive bias and measuring the effects on anxiety. Interpretive bias was modified by having participants read ambiguous stories that ended with a word fragment requiring a completion. Fragment

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completion resolved the ambiguity resulting in either a positive or negative meaning of the story. Results showed that the modification of interpretive bias successfully resulted in a concomitant change of anxiety. Participants in the negative condition became more anxious while anxiety dropped in the positive condition. This Cognitive Bias Modification of Interpretations (CBM-I) method fuelled many new experiments and the original findings have been replicated several times (e.g. Mackintosh, Mathews, Yiend, Ridgeway and Cook, 2006; Salemink, van den Hout and Kindt, 2007b; Yiend, Mackintosh and Mathews, 2005).

The conclusions that have been drawn about causality are based on the crucial assumption that the CBM-I procedure affects interpretive bias, and that the changed interpretive bias *then* affects anxiety. In other words, the assumption is that there is an *indirect* relationship between the CBM-I procedure and anxiety, mediated by an altered interpretive bias. As far as we know, this critical assumption has never been tested. Note, however, that this hypothetical cascade of CBM-I→ interpretative bias→ changed anxiety represents only one of several possible interpretations of the observed data. For instance, the CBM-I procedure could have a direct effect on anxiety by changing mood through abundant exposure to either positive or negative information. This direct effect could be an additional effect, added to the indirect one; or it could fully explain the effects on anxiety. As CBM-I effects on anxiety have been taken as evidence for a causal relationship between interpretive bias and anxiety, it is crucial to know how CBM-I affects anxiety and whether the effects on anxiety are mediated by changed interpretations. In the present paper this is examined in two studies.

Study 1

To get a first impression of the possible relationships between CBM-I and anxiety, we re-analyzed data from an earlier study (Salemink et al., 2007b) using a mediation path analysis. There are three possibilities: 1) CBM-I affects the interpretive bias, which in turn affects anxiety. Changes in anxiety are then caused by altered interpretations and not by the modification procedure itself; 2) There is both a direct and an indirect effect of CBM-I on anxiety; 3) CBM-I directly affects anxiety. That is, the modification procedure directly causes changes in anxiety due to mood induction, with no mediating role for interpretive bias. To investigate whether CBM-I affects current anxious state in different ways than more stable tendencies to feel anxious, both state and trait anxiety were measured.

Method

CBM-I data by Salemink et al. (2007b) were re-analyzed. Eighty-one unselected students participated for course credit (77 female/4 male). Their mean age was 21.1 years ($SD = 2.8$).

Materials and results

To modify interpretive bias, participants read ambiguous social stories, which ended with a word fragment (Mathews and Mackintosh, 2000). Solution of the fragment resolved the ambiguity in a positive or negative way, depending on the assigned condition ($n = 40$ in the positive and $n = 41$ in the negative condition). During CBM-I, “probe word fragments” were presented that were similar to the modification stories, but ended in a fragmented word with fixed positive and negative valence, irrespective of modification condition. Time taken to solve

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these probe fragments was used as a reaction time measure for interpretive bias, and results showed that compared to the negatively trained participants (M_{pos} = 1347ms, *SD* = 434; M_{neg} = 1318ms, *SD* = 491, $t(40) = 0.43$, *ns*), positively trained participants were faster in solving positive continuations of the story than negative continuations (M_{pos} = 1326ms, *SD* = 453; M_{neg} = 1513ms, *SD* = 467, $t(39) = -4.62$, $p < .001$).

After CBM-I, participants read a new set of 10 social stories that remained ambiguous (recognition task). Afterwards, four interpretations of each story were presented; (a) *possible* positive and (b) *possible* negative interpretation, and (c) positive and (d) negative *foil* sentence. Participants rated each interpretation for its similarity in meaning to the original story (1 = very different in meaning and 4 = very similar in meaning). Results showed that positively trained participants interpreted the new ambiguous information more positively compared to negatively trained participants (M_{pos} = 3.25, *SD* = 0.25; M_{neg} = 2.83, *SD* = 0.45, $t(79) = -5.14$, $p < .001$). In contrast to the standard manipulation checks, no effects were observed on two other interpretive bias tasks, suggesting limited generalizability of the trained interpretive bias.

Change in anxiety was measured with the state and trait versions of the State-Trait Anxiety Inventory (STAI, Spielberger, Gorsuch, Lushene, Vagg and Jacobs, 1983). Participants in the negative condition became more state anxious (M_{before} = 33.1, *SD* = 4.9; M_{after} = 35.7, *SD* = 7.6, $t(40) = -2.57$, $p < .05$), while positively trained participants got less anxious (M_{before} = 35.9, *SD* = 9.0; M_{after} = 33.0, *SD* = 6.7, $t(39) = 3.28$, $p < .01$). Regarding trait anxiety, positively trained participants became less trait anxious (M_{before} = 34.9, *SD* = 6.6; M_{after} = 33.3, *SD* = 6.6, $t(39) = 3.39$, $p < .01$), while the change in the negatively trained group was not significant (M_{before} = 34.2, *SD* = 5.9; M_{after} = 33.9, *SD* = 6.4, $t(40) = 0.60$, *ns*).

Statistical analyses

Mediation analyses were carried out separately for the two indices of induced interpretative bias: reaction time data and recognition data ($r = -.26$). The indices were calculated by subtracting the means for negative information from that of positive information.

A stepwise procedure was used to test two models. Based on the theoretical framework, the first model represents the indirect effect, with the interpretive bias mediating the relationship between CBM-I and anxiety. It consists of a path from CBM-I to the interpretive bias and a path from the interpretive bias to change in anxiety. Model 2 includes a direct path from CBM-I to anxiety. The fit of the models was evaluated using the chi-square goodness-of-fit test. As this test is criticized for its dependence on sample size, absolute (root mean square error of approximation, RMSEA) and incremental fit (comparative fit index, CFI) indices were included. As the sample size was relatively small for structural equation modelling, a bootstrap method was performed that showed that the statistics under consideration were unbiased (Efron and Tibshirani, 1993).

Results

State anxiety

First, the model representing the indirect effect between CBM-I and state anxiety through interpretive bias (Model 1) was analyzed using the reaction time index. This model did not fit the data ($\chi^2(1) = 11.9$, $p < .001$, CFI = .48, RMSEA = .37). The second model (including a

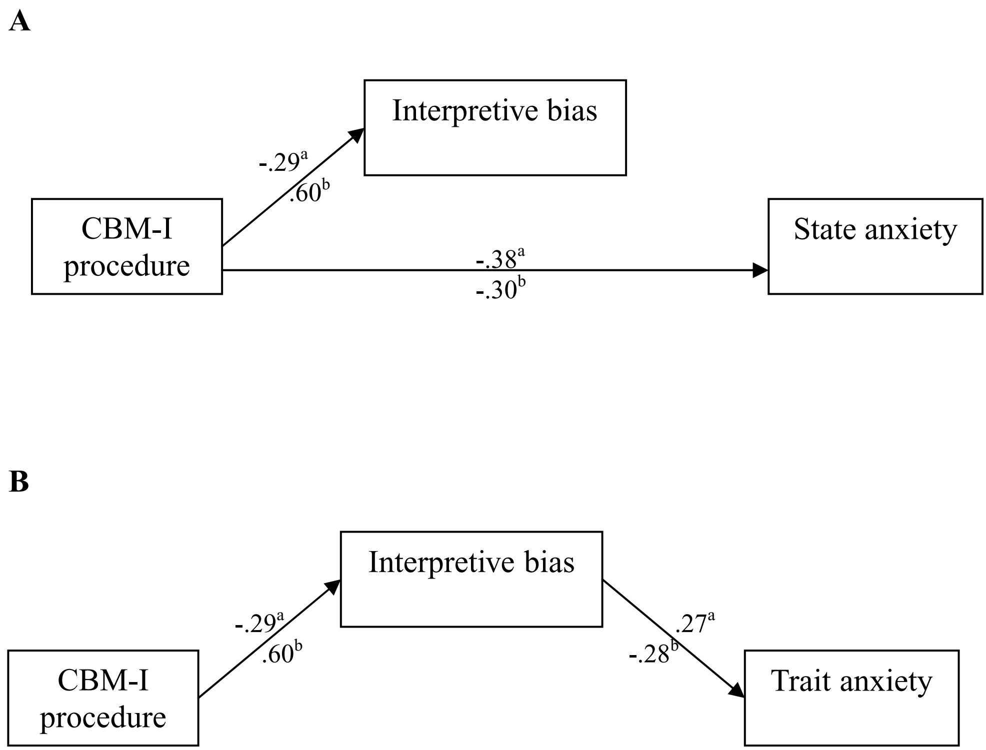

Figure 1. The direct effect of CBM-I on interpretive bias and state anxiety (A) and the indirect relationship between CBM-I and trait anxiety through interpretive bias (B)
Note. Values on the paths are path coefficients (standardized betas).
[a] Standardized beta for the reaction time interpretive bias measure.
[b] Standardized beta for the recognition interpretive bias measure.

direct path from CBM-I to anxiety) resulted in a fully saturated model, hence with no degrees of freedom left (χ^2 (0) = 0). This model had a significantly better fit ($\chi^2_{\text{difference}} = 11.9$, $\Delta df = 1$, $p < .001$). The CBM-I procedure was a significant predictor of change in anxiety ($r = -.42$, $\beta = -0.38$, $p < .001$) with positive modification resulting in a reduction of anxiety. Furthermore, CBM-I was a significant predictor of interpretive bias ($r = .29$, $\beta = -0.29$, $p < .01$), while the interpretive bias was not a significant predictor of anxiety. The final model accounted for a total of 19% of the variance in anxiety and 8% of the variance in interpretive bias.

Using the recognition data, Model 1, again, did not fit the data (χ^2 (1) = 5.38, $p < .05$, CFI = .91, RMSEA = .23). Model 2 fit significantly better (χ^2 (0) = 0, $\chi^2_{\text{difference}} = 5.38$, $\Delta df = 1$, $p < .05$). Again, the CBM-I procedure was a significant predictor of anxiety ($r = .42$ $\beta = -0.30$, $p < .05$) and interpretive bias ($r = .53$, $\beta = 0.60$, $p < .001$). Interpretive bias did not predict change in anxiety. The final model accounted for 20% of the variance in anxiety change and 36% of the variance in interpretive bias.

In sum, changes in state anxiety were not related to the interpretive bias; they were caused by direct effects of the CBM-I procedure. Thus, the interpretive bias did not mediate the relationship between CBM-I and changes in state anxiety (Figure 1, part A).

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Trait anxiety

Similar analyses were performed using trait anxiety as the dependent variable. The first model tested the indirect effect (reaction time measure) and provided a good fit to the data (χ^2 (1) = 1.7, $p = .19$, CFI = .94, RMSEA = .09). Model 2 did not result in a significant improvement of the model ($\chi^2_{difference} = 1.7$, $\Delta df = 1$, $p = .19$). The model consisting only of indirect effects represented the trait anxiety data most accurately, with CBM-I being a significant predictor of interpretive bias ($r = .29$, $\beta = -0.29$, $p < .01$) and interpretive bias predicting change in trait anxiety ($r = .27$, $\beta = 0.27$, $p < .05$). This model accounted for 8% of the variance in interpretive bias and 7% of the variance in trait anxiety.

With the recognition data, similar results were obtained. The first model resulted in a good fit to the data (χ^2 (1) = 0.24, $p = .62$, CFI = 1.00, RMSEA = .00). The second model did not significantly improve the model's fit ($\chi^2_{difference} = 0.24$, $\Delta df = 1$, $p = .62$). In the first model, CBM-I was a significant predictor of interpretive bias ($r = .53$, $\beta = 0.60$, $p < .001$) and interpretive bias was a significant predictor of changes in trait anxiety ($r = .25$, $\beta = -0.28$, $p < .01$)[1]. The CBM-I accounted for 36% of the variance in interpretive bias, which in turn explained 8% of the variance in trait anxiety.

In sum, changes in trait anxiety observed after a CBM-I procedure are due to the modified interpretive bias (Figure 1, part B).

Study 2

Mediation analyses suggested that changes in state anxiety were directly caused by the CBM-I procedure itself. Given the widespread use of the CBM-I procedure, it appeared worthwhile to further study what elements of the procedure are responsible for the observed effects on state anxiety. In the original CBM-I studies the disambiguation of the social scenarios and the active generation of solutions for the word fragments were seen as the crucial elements in affecting mood. To test the role of these elements and to test the alternative hypothesis that *mere exposure* to valenced materials would be sufficient to affect state anxiety, participants were exposed to positive or negative materials much as they were in the original CBM-I procedure, but this time it was not preceded by an ambiguous social story. Half of the participants were asked to complete word fragments (completion yielded positive or negative words), while the others were exposed to complete words (that had either a positive or negative valence). Using the argument that CBM-I could affect state anxiety through exposure to valenced information, it was predicted that the exposure to positive information (whether presented as completed or incomplete words) would result in a decline in anxiety and the exposure to negative information would result in an increase.

Method

Participants

Eighty-nine unselected students participated (74 female/15 male); 45 participants were in the positive exposure condition (23 in the complete words vs. 22 in the fragmented words

[1]Considering that the CBM-I procedure directly influenced state anxiety, it is conceivable that changes in state anxiety caused changes in trait anxiety. Analyses revealed that this was not the case; change in state anxiety did not predict change in trait anxiety (reaction time: $\beta = 0.16$, *ns*; recognition task: $\beta = 0.13$, *ns*).

condition) and 44 in the negative exposure condition (22 in both the complete and fragmented words condition). Their mean age was 21.5 years ($SD = 2.8$).

Materials

The words used in the present study were used in earlier CBM-I studies. As in some cases removing the ambiguous story resulted in words that lacked the intended modification valence and some words had multiple solutions, such words were replaced (60 words = 35%) with words from two blocks that were used in earlier studies. The number of trials was similar to that of earlier CBM-I studies; eight blocks, each containing 13 words. Eight words were the so-called (mood) induction words; these are the crucial words with a positive or negative valence. Two words were the so-called probe words and three other words were included as fillers. Stimuli were presented in a random order in each block.

Participants in the fragment completion condition were asked to complete the fragments as quickly as possible by pressing the spacebar as soon as they could think of the correct completion. They were then asked to type in the first missing letter of the fragment and the completed word was displayed for 1 s. Trials in this condition had a duration of approximately 2880 ms and therefore trials in the complete word condition also lasted for 2880 ms. Participants in this latter condition were instructed to read and pay attention to the words. To check whether interpretations were inadvertently changed, interpretations were assessed with the recognition task.

Procedure

Participants were allocated at random to one of the experimental conditions. The computer-program started with the state and trait versions of the STAI. Then participants either carried out the positive or the negative condition and either the complete or the fragmented word condition. This was followed by the second STAI-state and the recognition task.

Results

Anxiety

A 2 (valence) x 2 (word-type) x 2 (time) ANOVA indicated a Valence x Time interaction, $F(1, 85) = 4.21$, $p < .05$, $\eta_p^2 = .05$. There was a trend in the predicted direction for anxiety to decrease in the group who had processed positive information, $t(44) = 1.70$, $p < .10$ ($M_{pre} = 33.4$, $SD = 8.2$; $M_{post} = 32.1$, $SD = 6.6$) as opposed to a non-significant increase in the group who had processed negative information, $t(43) = -1.2$, *ns* ($M_{pre} = 33.7$, $SD = 8.6$; $M_{post} = 34.8$, $SD = 7.9$). Thus, independent of word type, mere exposure to valenced information seemed to have congruent effects on state anxiety.

Interpretations

A 2 (valence) x 2 (word-type) x 2 (recognition sentence type) x 2 (valence recognition sentence) ANOVA was performed on the recognition data. Besides simple main effects of sentence type and valence recognition sentence, all results, including any effects with exposure valence or word-type, were not significant. As intended, there are no indications of differences in interpretations.

Discussion

CBM-I procedures have been used to test the causal nature of the relationship between interpretive bias and anxiety by modifying interpretive bias and examining direct effects on state and trait anxiety. It is easy to conclude that the bias causes observed changes in affect. The current mediation analyses tested this causal pathway and revealed that changes in trait anxiety were indeed caused by the altered interpretations. Interestingly, there was in fact no relationship between an altered interpretive bias and changes in state anxiety. Given that these initial findings were only based on statistical analyses, an experiment was designed to directly test whether an element of the CBM-I procedure (exposure to valenced materials) could affect anxiety. This study showed that exposure to positive or negative words was sufficient to produce (small) changes in state anxiety.

A weakness of the present study is that the original CBM-I procedure was not incorporated in the second experiment and thus a direct comparison between anxiety changes instigated under CBM-I and present conditions is not possible. When comparing the present effect size regarding group differences in state anxiety ($d = 0.44$) with earlier effect sizes (Mathews and Mackintosh, 2000: $d = 1.55$, Salemink, van den Hout and Kindt, 2007a; Salemink et al., 2007b: $d = 0.27$ and 0.92, Yiend et al., 2005: $d = .86$ and $d = 0.23$) then it reveals that the effect sizes fluctuate strongly. The present effect size does fall in the range of observed effects; however it seems likely that CBM-I has an additional effect on state anxiety besides exposure to valenced material. A direct comparison between the full CBM-I and a dismantled version remains an issue for further research.

The finding that interpretive bias seems to affect trait, but not state anxiety, is surprising as trait anxiety is defined as the stable tendency to react with state anxiety to stressful situations. Furthermore, state and trait anxiety scores are generally highly correlated. One possibility is that questions about one's present state may be answered by a simple introspection of one's current mood. Whereas inferring your feelings of general anxiety (trait anxiety) seems more of an elaborative process involving activation of the autobiographical data set, scanning it and evaluating it against the question being asked. This process might, thereby, leave more room for the interpretive bias to exert its influence. Note that the observed effects on trait anxiety are consistent with earlier findings of CBM-I affecting the degree to which individuals respond anxiously to a stress task (Mackintosh et al., 2006; Wilson, Macleod, Mathews and Rutherford, 2006).

In sum, the present study showed that changes in state anxiety were not related to changes in interpretive bias and the former is thus not a valid indicator of a causal relationship. This bears implications for previous CBM-I experiments where conclusions about causality have been drawn after observing such changes in state anxiety. The relationship between CBM-I and changes in trait anxiety is, on the other hand, mediated by the interpretive bias. This is promising in the light of possible clinical application. Given that interpretive bias affects trait anxiety (a long lasting vulnerability factor for developing anxious mood), inducing a more positive interpretive bias in patients with an anxiety disorder should have beneficial effects on their trait anxiety level. Steps are being taken to examine whether the CBM-I method can be used as a tool in treating anxious individuals.

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References

Beck, A. T. and Clark, D. A. (1988). Anxiety and depression: an information processing perspective. *Anxiety Research, 1*, 23–36.

Efron, B. and Tibshirani, R. J. (1993). *An Introduction to the Bootstrap*. New York: Chapman and Hall Publishers.

Mackintosh, B., Mathews, A., Yiend, J., Ridgeway, V. and Cook, E. (2006). Induced biases in emotional interpretation influence stress vulnerability and endure despite changes in context. *Behavior Therapy, 37*, 209–222.

Mathews, A. and Mackintosh, B. (2000). Induced emotional interpretation bias and anxiety. *Journal of Abnormal Psychology, 109*, 602–615.

Salemink, E., van den Hout, M. A. and Kindt, M. (2007a). Trained interpretive bias and anxiety. *Behaviour Research and Therapy, 45*, 329–340.

Salemink, E., van den Hout, M. A. and Kindt, M. (2007b). Trained interpretive bias: validity and effects on anxiety. *Journal of Behavior Therapy and Experimental Psychiatry, 38*, 212–224.

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R. and Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory*. Palo Alto: CA: Consulting Psychologists Press.

Wilson, E. J., Macleod, C., Mathews, A. and Rutherford, E. M. (2006). The causal role of interpretive bias in anxiety reactivity. *Journal of Abnormal Psychology, 115*, 103–111.

Yiend, J., Mackintosh, B. and Mathews, A. (2005). Enduring consequences of experimentally induced biases in interpretation. *Behaviour Research and Therapy*, *43*, 779–797.