



King's Research Portal

Document Version
Peer reviewed version

[Link to publication record in King's Research Portal](#)

Citation for published version (APA):

Hirsch, C. R., Krahé, C., Whyte, J., Bridge, L., Loizou, S., Norton, S., & Mathews, A. (Accepted/In press). Effects of Modifying Interpretation Bias on Transdiagnostic Repetitive Negative Thinking. *Journal of Consulting and Clinical Psychology*.

Citing this paper

Please note that where the full-text provided on King's Research Portal is the Author Accepted Manuscript or Post-Print version this may differ from the final Published version. If citing, it is advised that you check and use the publisher's definitive version for pagination, volume/issue, and date of publication details. And where the final published version is provided on the Research Portal, if citing you are again advised to check the publisher's website for any subsequent corrections.

General rights

Copyright and moral rights for the publications made accessible in the Research Portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognize and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the Research Portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the Research Portal

Take down policy

If you believe that this document breaches copyright please contact librarypure@kcl.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.

Effects of Modifying Interpretation Bias on Transdiagnostic Repetitive Negative Thinking

Colette R. Hirsch¹, Charlotte Krahé¹, Jessica Whyte¹, Livia Bridge¹, Sofia Loizou¹, Sam Norton¹, and Andrew Mathews²

¹Department of Psychology, Institute of Psychiatry, Psychology and Neuroscience, King's College London, London, UK.

²Department of Psychology, University of California, Davis, California, USA

Date submitted: 12th October 2018

Date resubmitted: 9th May 2019

Date accepted: 16th September 2019 Journal of Consulting and Clinical Psychology

Correspondence:

*Dr Colette Hirsch

Department of Psychology, Institute of Psychiatry, Psychology and Neuroscience,

King's College London,

16 De Crespigny Park,

London SE5 8AF

Email: colette.hirsch@kcl.ac.uk

Abstract

Repetitive negative thinking (RNT; e.g. worry and rumination) is common across emotional disorders, as is the tendency to generate negative interpretations (interpretation bias).

Ameliorating negative interpretations via cognitive bias modification of interpretations (CBM-I) reduces worry/rumination, and improves mood in people diagnosed with GAD or Depression.

We investigated whether these findings generalize to high worry or rumination populations, irrespective of diagnosis, and whether effects are increased by enhancing emotional engagement with training with active generation of positive resolutions of ambiguity and imagery.

Method: Community volunteers with excessive worry and/or rumination who were above clinical cut-off on anxiety and/or depression measures, were allocated to an active control condition (N=54), interpretation training with prior activation of RNT (CBM_RNT; N=54), or training augmented with positive outcome generation and imagery (CBM_ENH; N=53). Interpretation bias, RNT, and mood were assessed before and following 10 internet-based sessions completed within a one-month period. RNT and mood questionnaires were also completed at 1-month follow-up.

Results: After training, both forms of CBM-I (vs. control) facilitated more positive interpretations and reduced negative intrusions during a worry task. At one-month follow-up, anxiety, depression, RNT, and worry in the past week were lower in the CBM-I than control conditions, but not rumination or trait worry.

Compared to standard CBM-I, the augmented form facilitated more positive interpretations, reduced negative intrusions after training, and reduced trait rumination at one-month follow-up, but it did not augment effects on trait worry, anxiety or depression.

Conclusions: Interpretation bias maintains transdiagnostic RNT and internet-based CBM-I can reduce longer-term RNT.

Key words: interpretation bias; cognitive bias modification (CBM); repetitive negative thinking (RNT); worry; rumination

Public Health Significance Statement

Worrying about the future or mulling over negative events from the past (rumination) is common in people experiencing anxiety and depression. Importantly, these types of unhelpful repetitive negative thinking can maintain anxious and depressed mood. This study indicates that simple regular practice in making positive interpretations of emotionally ambiguous information reduces repetitive negative thinking and improves mood in people with high levels of worry or rumination.

Effects of Modifying Interpretation Bias on Transdiagnostic Repetitive Negative Thinking

Repetitive negative thinking (RNT) is a common and distressing transdiagnostic process involving perseverative thinking, which is particularly common in people experiencing symptoms of anxiety or depression (Ehring & Watkins, 2008). In anxiety, the most common form of RNT is excessive worry (usually about future dangers), and uncontrollable worry about many different topics is a central diagnostic criterion for Generalized Anxiety Disorder (GAD). Similar RNT is often reported in depression, sometimes more focused on personal inadequacies or symptoms, and referred to as rumination. Both forms of RNT can occur across different diagnoses, although rates of worry are greater in GAD than depressed individuals, and vice versa for rumination (Krahé, Whyte, Bridge, Loizou, & Hirsch, in press). Because both worry and rumination are common across diagnoses, and can be modified by similar methods (Hirsch et al. (2018), we suppose that they are maintained by the same underlying cognitive mechanisms.

Hirsch and Mathews (2012) theorized that one form of RNT (pathological worry) is maintained by three interacting processes: cognitive biases, such as habitual interpretation of emotionally ambiguous events in a negative manner; thinking in a quasi-verbal form rather than imagery; and impaired or misdirected voluntary attentional control. For example, thinking in quasi-verbal and relatively abstract form (rather than more concrete mental images) is dominant when anyone worries (Hirsch, Hayes, Mathews, Perman, & Borkovec, 2012), or ruminates (Watkins & Moulds, 2007), and such verbal processing prolongs subsequent RNT. High worriers instructed to worry using imagery were less likely to report later negative thought intrusions than were those instructed to worry in their usual verbal form (Stokes & Hirsch, 2010; Hirsch, Perman, Hayes, Eagleson, & Mathews, 2015).

Similarly, engaging in less abstract and verbal thinking reduces rumination (Watkins & Moulds, 2007), suggesting that the same processes underlie rumination.

Other related research has shown that negative interpretative bias is a transdiagnostic process evident across emotional disorders (Hirsch, Meeten, Krahe, & Reeder, 2016) and is associated with higher levels of worry and rumination (Krahe et al., in press). Importantly, interpretation bias has been shown to have a causal role in maintaining RNT in the short term (Hirsch, Hayes, & Mathews, 2009; Hayes, Hirsch, Krebs, & Mathews, 2010; Hertel, Mor, Ferrari, Hunt, & Agrawal, 2014). Longer term effects were demonstrated in a multi-session study of worry and rumination, in which Hirsch et al. (2018) randomly allocated volunteers diagnosed with GAD or Depression to training procedures involving repeated presentation of initially ambiguous scenarios, which either described common worry (GAD participants) or rumination topics (depressed participants). In the active training conditions, scenario ambiguity was consistently resolved positively; while in the control condition participants were presented with the same ambiguous scenarios that remained unresolved, leaving participants free to interpret them as they saw fit. Results revealed that the experimental training methods were more effective than the control procedure in facilitating positive interpretations, and importantly, both worry and rumination was reduced, together with improved mood, at follow-up one-month later. Overall, the results obtained by Hirsch et al. (2018) support the supposition that worry and rumination are maintained, at least in part, by transdiagnostic processes such as interpretation bias, and that modifying this bias reduces both forms of RNT in those with clinical diagnoses of depression or GAD.

Hirsch et al. (2018) also tested the idea that interpretation bias modification can be enhanced by activating emotional concerns immediately prior to re-training. Williams, Mathews, and Hirsch (2014) had previously demonstrated that attentional bias to threat was more evident in high worriers following normal verbal worry (compared to worry in imagery

form), suggesting that RNT activates cognitive bias. Further support was provided in a multi-session home-based training study of social anxiety, in which attention was effectively modified only when training was preceded by exposure to social threat situations (Kuckertz et al., 2014; Carlbring et al., 2012), consistent with the idea that activation of emotional concerns makes related cognitive biases more accessible and thus potentially more malleable.

In an attempt to address this possibility, Hirsch et al. (2018) included two types of interpretation bias training, differing only in that one condition required participants to actively worry (people with GAD) or ruminate (people with depression) on their personal problems immediately prior to training sessions. Although the RNT activation manipulation appeared to enhance some effects, the differences between the two CBM groups on outcome measures did not reach statistical significance, thus providing no clear support for the hypothesis that activation of emotional concerns is a critical factor in modifying RNT. Nonetheless, because some numerical trends favored the activation condition, it cannot be concluded that enhancing emotional arousal had no beneficial effects, so it was retained in CBM procedures used in the present study.

Enhancing the effects of interpretation training may be achievable in other ways. Research on emotional imagery has shown that generating mental images of positive descriptions usually elicits greater emotional responses than does focusing on the verbal meaning of the same descriptions (Holmes & Mathews, 2005; Mathews, Ridgeway, & Holmes, 2013). Furthermore, repeated practice in imagining the positive resolution of ambiguous descriptions resulted in greater elicitation of positive feelings about new ambiguous events than did similar practice without instructions to use mental imagery (Holmes, Mathews, Dalgleish, & Mackintosh, 2006).

Beyond imagery, simply requiring participants to actively generate meanings of ambiguous stimuli for themselves, as opposed to simply being exposed to the same meanings,

also results in enhanced emotional responses to later ambiguous test stimuli (Hoppitt, Mathews, Yiend, & Mackintosh, 2010) and in transfer effects to mood measures (Mathews & Mackintosh, 2000). In sum, active generation of positive meanings, using imagery or other methods, seems to enhance the positive emotional response to interpretation training. Interestingly, to date only one other study using scenario-based CBM-I has included instructions for participants to actively generate their own positive resolutions to ambiguity. Rohrbacher, Blackwell, Holmes, and Reinecke (2014) compared imagery-enhanced interpretation bias training with and without active generation of outcomes, but found no evidence to support the idea that including active generation produced superior training effects. However, this single session study used a non-selected sample who were unlikely to lack a positive bias, rather than individuals with high levels of RNT who do lack a positive bias (Krahé et al., 2019) and thus may benefit more from explicit efforts to generate positive outcomes. Furthermore, it remains to be investigated whether generating one's own positive resolutions, combined with imagery of these positive outcomes over multiple sessions could enhance far transfer to mood and other symptoms in a sample of participants with high levels of RNT.

Furthermore, evidence reported by Standage, Harris, and Fox (2014) also suggests that the type of emotional engagement with interpretation training materials may be critical to successful modification and associated transfer to emotional reactivity. Specifically, participants in a CBM study who thought of the training scenarios as happening to someone else, or that the positive resolutions could not apply to themselves, failed to improve. In contrast, those who reported identifying themselves with the protagonist in the scenarios were effectively trained, and this led to associated mood changes in response to stress. The importance of self-identification with positive outcomes might contribute to the lack of far transfer in other research. For example, while Grol et al. (2018) found that interpretation

training (similar to our standard condition) promoted a more positive interpretation bias and reduced anxiety levels in high worriers, it did not reduce trait worry or intrusions in a worry task as compared to a control condition. Consequently, in the present study, we attempted to enhance emotional engagement in interpretation training via instructed practice in self-identification: specifically, by actively generating positive resolutions to the ambiguity and imagining oneself in the positively resolved situations.

Hirsch et al. (2018) demonstrated that interpretation training can be helpful for those with clinical diagnoses of GAD or Depression, when focused on worry or rumination materials, respectively. However, RNT is a widespread problem, regardless of diagnosis (Watkins, 2008). It remains unclear whether those reporting high levels of RNT and symptoms of anxiety and/or depression without necessarily having a specific diagnosis of GAD or major depressive disorder, would also benefit from interpretation bias modification. The study reported here consequently focused on participants reporting excessive worry and/or rumination and who were also experiencing anxiety and/or depression symptoms. Participants were allocated to one of two forms of interpretation training (with materials focused on their dominant form of RNT, worry or rumination, at the time of assessment): one form of training was that used in Hirsch et al. (2018); and a second form included additional instructions to actively generate positive resolutions to ambiguous descriptions, and to imagine oneself in that situation (see Method below for details). Thus, by enhancing personal emotional engagement with positive outcomes of ambiguous scenarios used in interpretation training, we tested whether this condition would be superior to the other standard training condition in terms of facilitating a more positive interpretation bias at the end of training, and consequently improving RNT and mood at one-month follow-up. However, based on Hirsch et al. (2018) we expected both active training conditions to be superior to a third control condition in which (as before) the same ambiguous scenarios were presented but without

specific guidance as to their resolution. Hence, we hypothesized that both active training conditions would facilitate more positive interpretations than the control condition, and also reduce RNT and negative mood more at one-month follow-up. Secondly, we hypothesized that the enhanced engagement condition would be more effective than the comparison interpretation training condition (without imagery or active generation).

Method

Design

Community volunteers with high levels of worry or rumination were randomly allocated to one of three conditions: CBM-I with prior RNT (henceforth CBM_RNT); CBM-I enhanced with extra positive outcome generation and positive imagery (henceforth CBM_ENH); or an active control condition (henceforth CONTROL). Tasks assessing interpretation bias and behavioral measures of worry and rumination were administered during study visits prior to and following 10 computerized training sessions that were completed within a one-month period. Questionnaire measures of RNT and mood were completed online prior to and following the block of 10 training sessions, and additionally at one-month follow-up. A flow chart of the experimental procedure is presented in Figure 1 in Integral Supplemental Materials.

Participants

One hundred and eighty-six participants with high levels of worry or rumination were recruited from the community via advertisements on websites, in newspapers, and university circular emails and completed at least the first visit at King's College London. The CONSORT diagram is presented in Figure 2 in Integral Supplemental Materials. Participants had to be fluent in English, with normal or corrected hearing, and aged between 18 and 65 years old. They were initially screened for levels of high worry and rumination, that is, a

Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990) score ≥ 62 and/or a Ruminative Response Scale (RRS; Nolen-Hoeksema & Morrow, 1991) score ≥ 63 ¹. Additionally, participants were screened for clinical levels of anxiety and/or depression, that is, a total score ≥ 10 on the GAD-7 (Spitzer, Kroenke, Williams, & Löwe, 2006), and/or PHQ-9 (Kroenke & Spitzer, 2002). Individuals taking psychotropic medication had to be stabilized on that dose for at least 3 months. Exclusion criteria were: severe depression (≥ 23 PHQ-9 score), past or current risk to self (self-harm in past 12 months/ suicide attempt in last 2 years/ PHQ-9 suicidal ideation item 9 scored > 1), co-morbid psychosis, bipolar disorder, borderline personality disorder or substance abuse, non-normal/ not corrected to normal hearing, as well as current or recent (past 6 months) psychological treatment.

Participants completed questionnaire measures again within the 24 hours prior to the first study visit. Participants in the CBM conditions were allocated to either worry or rumination training materials based on these PSWQ and RRS scores. Participants with a total PSWQ score of ≥ 62 were allocated to the worry materials, and participants with a total RRS score of ≥ 63 were allocated to the rumination materials. If participants scored above the cut-offs on both questionnaires, separate z scores for PSWQ and RRS (based on the Hirsch et al., 2018, pre-training data) were used, with allocation based on the higher z score.

Our power calculation, based on initial pilot work, indicated that, assuming a correlation between baseline and follow-up of $r = .4$, we would have 80% power to detect $d = .5$ with 53 participants per group (i.e., a total $N = 159$) at the 5% significance level. Anticipating 12% drop out, we enrolled 178 participants in the study. Of these 178 participants, all completed visit 1 (baseline visit), 12 (6.7%) subsequently dropped out, 4

¹ These specific forms of RNT were used since Hirsch et al. (2018) had developed tailored training materials specifically for worry or rumination.

(2.2%) completed fewer than 8 / 10 online sessions or returned for the second (post-training) visit more than one month after the first visit (and thus did not count as ‘completers’; see below), and 1 (0.6%) was excluded due to consistently poor task performance. The final sample used in the analyses comprised 161 individuals, with 54 in the CONTROL and 54 in CBM_RNT (38 allocated to worry materials and 16 to rumination materials) conditions, and 53 in the CBM_ENH condition (33 allocated to worry materials and 20 to rumination materials)².

For descriptive purposes, we estimated the likelihood that participants would meet diagnostic criteria for GAD and/or depression using Computerized Adaptive Testing - Mental Health (CAT-MH), a computerized tool using adaptive testing to provide probability estimates for meeting diagnostic criteria for psychiatric conditions. We administered the CAT-ANX (Gibbons et al., 2014) and CAT-DI (Gibbons et al., 2012) tests to examine probability of diagnosis of GAD, depression and both disorders in our sample. With a cut-off of probability of .9, 34 (21%) participants were likely to meet diagnostic criteria for GAD alone, 88 (55%) for Depression, and 29 (18%) both GAD and Depression. Participant demographic characteristics are presented in Integral Supplemental Table 1.

Randomization

Participants were randomized to one of the three conditions based on a random allocation sequence generated from <http://www.random.org> by a person not directly involved in the research study, who placed numbers 1–3 corresponding to the three conditions in sealed envelopes marked with ascending sequence order numbers. Participants were allocated to conditions according to this sequence and remained blind to the condition until the end of

² The final sample of 161 did not differ from the 17 excluded participants on depression, anxiety, rumination or general RNT or current weekly worry questionnaire measures at visit 1 ($t(176) = -.13, p = .895$ for PHQ-9; $t(176) = -.65, p = .519$ for GAD-7; $t(176) = 0.94, p = .349$ for RRS; $t(176) = -.03, p = .977$ for RTQ-T; $t(176) = -.15, p = .881$ for PSWQ-pw), but did differ in terms of trait worry as measured by the PSWQ ($t(176) = -2.83, p = .005$), with lower trait worry in those who were excluded ($M = 65.12, SD = 9.60$ for excluded participants, $M = 69.26, SD = 5.19$ for final sample).

the study (when they were debriefed). Researchers opened the envelope at the first experimental session once participants had provided written informed consent. Blinding of the researchers was not possible as researchers guided participants through the first online session, which differed by experimental condition (see below).

Experimental Conditions

All conditions involved 10 sessions: one completed during the initial visit, followed by nine sessions completed at home using an online platform over the following three weeks to one month³. Prior to the first CBM session, participants received either a mental imagery training exercise delivered by the experimenter (CBM_ENH) or a neutral filler task (CBM_RNT and CONTROL). All online sessions began with either an RNT induction (CBM_RNT and CONTROL). All online sessions began with either an RNT induction (CBM_RNT and CBM_ENH) or a neutral task (CONTROL). Then, participants listened to 40 (CBM_ENH) or 50 (CBM_RNT and CONTROL) audio clips (henceforth scenarios), imagined themselves in each described situation, and then answered a comprehension question.

Imagery training exercise or neutral filler task.

Imagery training exercise. Prior to the first online session, those in the CBM_ENH condition completed a training exercise in using mental imagery, which aimed to encourage participants to use vivid and positive mental imagery during the online sessions. The training was adapted from Holmes and Mathews (2005) and first involved imagining five neutral non-ambiguous scenarios described by the experimenter while the participants' eyes were closed. Participants rated imagery vividness on a scale from 1 (*not at all vivid*) to 5 (*extremely vivid*) and were provided with feedback to enhance imagery vividness as appropriate. A further five scenarios described ambiguous worry or rumination situations (depending on participants'

³ We allowed some leeway to complete any outstanding sessions; thus, the maximum time allowed to complete the sessions was one month.

material set allocation) with ambiguity resolved positively at the end.⁴ Participants imagined the positive ending, answered questions as before and rated how positive the image was on a scale from 1 (*not at all positive*) to 5 (*extremely positive*). The experimenter gave feedback to encourage vivid positive imagery.

Neutral filler task. To control for the time taken in CMB_ENH condition to complete the mental imagery training exercise in visit 1, participants in the CBM_RNT and CONTROL conditions completed a neutral filler task. They first completed a battery of questionnaires consisting of the Attentional Control Scale (ACS; Derryberry & Reed, 2002), emotional Attentional Control Scale (eACS; Barry, Hermans, Lenaert, Debeer, & Griffith, 2013), the Effortful Control Scale (EFS; a subscale of the Adult Temperament Questionnaire; Rothbart, Ahadi, & Evans, 2000), and the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973). Participants then completed a neutral computerized attention task where they indicated the direction of target arrows (Basanovic, Notebaert, Grafton, Hirsch, & Clarke, 2017).

Pre-scenario task: RNT induction or neutral task.

RNT induction. Participants in the CBM_ENH and CBM_RNT condition engaged in an RNT induction immediately prior to each online session. The RNT induction was that used by Hirsch et al. (2018), adapted from Hertel et al. (2014). Participants selected one of three themes about which they had recently found themselves worrying (for those allocated to training using worry materials) or ruminating (for those allocated to training using rumination materials). Each theme could be selected only once a week (three times in total). Participants wrote a one-line summary of their RNT topic, which was displayed on subsequent screens. They then wrote down their usual negative thoughts about the topic for three minutes. Finally, they worried/ruminated silently about their topic for two minutes and then rated their

⁴ An additional two scenarios were presented if the participant needed extra practice.

current level of worry, rumination, anxiety, and depression on 0 to 100% visual analogue scales⁵.

Neutral grammar task. To control for the time taken for CBM-I conditions to complete RNT inductions prior to each online session, participants in the CONTROL condition completed a neutral grammar task. They read neutral stories and made grammatical correctness judgments. At the end of the stories, they completed comprehension questions and rated their level of worry, rumination, anxiety, and depression.

Main online scenario-based task.

CBM_ENH. Each session, participants heard 40 worry or rumination related scenarios (depending on material set allocation) used in Hirsch et al. (2018).⁶ Twenty scenarios were resolved in a positive manner, while 20 remained unresolved. When presented with the unresolved scenarios, participants were asked to generate their own positive ending. On all trials, they were instructed to vividly imagine the ending of the scenario for seven seconds. On 50% of trials, participants rated the positivity of the image, and on the other 50% they rated the vividness of the image on VAS scales (0 ‘not at all’ to 100 ‘extremely’).⁷ Feedback was provided to encourage participants to generate vivid and positive images. They also completed Yes/No ‘comprehension’ questions designed to reinforce the positive interpretations. Participants received feedback on the accuracy of these answers, except for the trials in which ambiguity had not been resolved, where feedback was provided only for correct trials. At the end of each online session, participants in this condition also completed two questions to reinforce identification with the positive outcome of the scenarios.⁸

⁵ See Integral Supplemental Materials for results.

⁶ These included materials developed by Mathews and Mackintosh (2000), Grol et al. (2018), Hirsch, Hayes, and Mathews (2009), Hayes, Hirsch, Krebs, and Mathews (2010), Holmes, Mathews, Dalgleish, and Mackintosh (2006), Hertel, Mor, Ferrari, Hunt, and Agrawal (2014), and Blackwell et al. (2015), as well as others developed by Hirsch et al. (in press).

⁷ Mean ratings (averaged across sessions) were $M = 77.85$ ($SD = 10.80$) for vividness and $M = 76.56$ ($SD = 10.02$) for positivity.

⁸ See Additional Supplemental Materials for questions and descriptive statistics.

CBM_RNT. This condition was identical to that used in Hirsch et al. (2018) and required participants to listen to 50 scenarios describing worry-related (worry materials) or rumination-related (rumination materials) situations, which were emotionally ambiguous but eventually resolved in either a positive (76% of the time), or negative manner (12%), or were left unresolved (12%) by the ending of the scenario. After each scenario, participants completed Yes/No ‘comprehension’ questions that required endorsement of a response in keeping with the interpretation provided in the scenario (i.e., a positive interpretation in positive trials and negative in negative trials). They received feedback on the accuracy of these answers, except for the trials in which ambiguity had not been resolved.

Control. As in Hirsch et al. (2018), control participants heard 50 ambiguous scenarios per session, which remained unresolved. Half of the scenarios were followed by a Yes/No ‘comprehension’ question (as above) relating to the ambiguity of the scenario, but which was never followed by feedback, so allowing either interpretation without correction. The remainder was related to a factual element, and these were followed by accuracy feedback.

Scenario identification ratings.

Two sets of identification ratings were developed from Standage et al. (2014). All participants completed *context identification ratings* twice, once immediately after the first training session at visit 1, and once at visit 2 in relation to all home-based sessions. These comprised eight items which participants were asked to complete in relation to the general context of the scenarios (i.e. the setting and what was happening, but not how the situation turned out) to assess how easy it was to identify with the context of the scenarios. Items (e.g., “I was able to put myself into the situations, so that it seemed as though they were happening to me.”; “I was able to imagine myself in situations I have not encountered in real life as though they were happening to me.”; “It was difficult to identify myself as the person experiencing the different situations.”) were rated on a scale from 1 (*Never*) to 7 (*All of the*

time). Items were reverse-scored as appropriate. Cronbach's alpha for visit 1 and 2 context identification item ratings were .82 and .87, indicating good internal consistency. Thus, for each visit, responses were averaged (after reverse-scoring items as appropriate) to produce a mean score.

To determine if CBM_ENH did lead to greater self-identification with positive outcomes than standard CBM_RNT, participants in the two CBM-I conditions also completed *positive outcome identification ratings*, which comprised five items relating to the positive outcome of the scenarios, that is, to how participants engaged with the resolution of the ambiguity when situations turned out positively (e.g., "*When I heard things turn out well, I thought things could go like that for me.*"; "*The positive outcomes I thought about were similar to how things might happen for me in real life.*"; "*When I heard things turn out well, I thought this would only happen to someone else, but not me.*") using the same 7-point response scale. Again, relevant items were reverse-scored. Cronbach's alpha for session 1 and 2 ratings were .85 and .82, indicating good internal consistency. Therefore, for each visit, we computed average scores (after reverse-scoring items as appropriate).

Interpretation Bias Measures

Scrambled sentences test. The scrambled sentences test was that used in Hirsch et al. (2018), and based on Wenzlaff and Bates (1998), that involved participants using five of six presented words to form grammatically correct sentences of either negative or positive valence. For example, "*looks the future bright very dismal*" could be unscrambled to form the sentence "*the future looks very bright*" (positive) or "*the future looks very dismal*" (negative). Participants were presented with 20 sentences to unscramble in five minutes, whilst holding in mind a string of six digits. Half the sentences related to worry themes, while half related to depressive rumination. The number of positive sentences divided by the total number of grammatically correct sentences generated serves as an index of interpretation bias, with a

higher index (scores range from 0 to 1) denoting a more positive interpretation bias. Two separate lists of 20 items were counterbalanced across participants over the two visits.

Recognition test. Based on Mathews and Mackintosh (2000), with materials used in Hirsch et al. (2018), participants read 20 ambiguous scenarios, completed word fragments of the final word (which did not resolve the ambiguity) and answered comprehension questions. After all scenarios had been completed, participants were presented with the title of each scenario, followed by four statements in random order. Two statements were consistent with resolution of ambiguity in the scenario in either a positive or negative way (targets), while the other two statements were positive or negative but were not legitimate interpretations (foils). Participants rated how similar each statement was to the meaning of the original scenario. A recognition test index was computed for each participant by subtracting mean ratings for negative targets from mean ratings for positive targets. Thus, higher scores denoted greater similarity ratings for positive vs. negative targets (i.e., a more positive interpretation bias). Participants completed the recognition test before and after the first online session at the first visit, and again at the second (post-training) visit; hence, three separate sets of 20 items (based on Mackintosh, Mathews, Yiend, Ridgeway & Cook, 2006; Mathews, Ridgeway, Cook & Yiend, 2007) were generated, with set order counterbalanced across participants.

Worry and Rumination Tasks

Behavioural measures of worry and rumination were presented in counterbalanced order across participants and order was kept consistent across the two study visits. Participants completed VAS mood ratings prior to the worry and rumination tasks, indicating their current levels of anxiety, sadness and happiness. To ensure that any mood changes from the first task did not influence performance on the second task, a neutral filler task (Baddeley, Emslie, & Nimmo-Smith, 1992) was completed after the first task.

Worry task. Adapted from Hirsch, Mathews, Lequertier, Perman, and Hayes (2013), participants engaged in worry about a current worry topic for five minutes. This was followed by a five-minute period in which participants focused on their breathing and indicated at random cued intervals whether they were focusing on their breathing or experiencing a thought intrusion. They categorized thought intrusions as negative, positive, or neutral.

Rumination task. Using Grisham, Flower, Williams, and Moulds' (2011) task, participants recalled a recent situation that made them feel down, regretful or bad about themselves. They then typed for 4 minutes, describing what happened and what they felt or thought following the event. Then a screen was displayed for 2 minutes with text explaining that the participants had to wait while the computer was 'processing data'. Then, participants rated 10 statements about what they thought and felt right now about the situation they had just described (e.g., "*Right now, I can't stop thinking about what happened*"; "*Right now, I wonder why I responded the way I did*"; "*Right now, I run the event through my head, over and over.*") on VAS scales ranging from '*completely untrue about me*' to '*completely true about me*'. Cronbach's alphas for the rumination task scales were .79 at visit 1 and .83 at visit 2, indicating good internal consistency.

Standardized Self-Report Questionnaires

Levels of trait repetitive negative thinking were measured using the Repetitive Thinking Questionnaire (RTQ-T [trait]; McEvoy, Tribodeau, & Asmundson, 2014; Cronbach's $\alpha = .81$ at baseline in the present sample). Trait worry levels were assessed using the PSWQ (Cronbach's $\alpha = .70$). Additionally, the Penn State Worry Questionnaire-Past Week (PSWQ-pw; Stöber & Bittencourt, 1998) was included to assess levels of worry over the past week (Cronbach's $\alpha = .84$). Trait rumination was measured using the RRS (Cronbach's $\alpha = .90$).

Depressive symptoms were assessed with Patient Health Questionnaire 9 (PHQ-9; Kroenke & Spitzer, 2002; Cronbach's $\alpha = .79$) and anxiety symptoms using the Generalized Anxiety Disorder 7-item scale (GAD-7; Spitzer et al., 2006; Cronbach's $\alpha = .79$).

The Spontaneous Use of Imagery Scale (SUIS; Reisberg, Pearson, & Kosslyn, 2003; Cronbach's $\alpha = .84$) was included at the first study visit to measure participants' tendencies to use mental imagery in their everyday lives.⁹

Procedure

Participants completed questionnaires (PSWQ, RRS, PHQ-9, GAD-7, SUIS, RTQ-T, PSWQ-pw) online within 24 hours prior to the first study visit. At the first visit, participants provided informed consent and were randomly allocated to one of the three conditions: 1) CBM_RNT, 2) CBM_ENH or 3) CONTROL (see *Experimental conditions* section above for details). Probability of diagnosis of GAD and/or depression was then assessed using the CAT-MH. Then participants completed the scrambled sentences test, recognition test, worry task, and rumination task (order of worry and rumination tasks was counterbalanced across participants). Participants were then given a brief study rationale¹⁰ for the online sessions and completed expectancy ratings.¹¹ Following this, participants completed either the mental imagery training exercise (CBM_ENH condition) or a neutral filler task (CBM_RNT &

⁹ This scale was included to assess participants' spontaneous use of mental imagery prior to the intervention. There was no difference between conditions at baseline, $F(2, 158) = .12, p = .890, M(SD) = 41.06 (9.81)$ for CBM_ENH, $M(SD) = 40.24 (9.74)$ for CBM_RNT and $M(SD) = 40.98 (9.48)$ for CONTROL.

¹⁰ All participants were given the same overall information/rationale about the study. They were told that the online sessions would involve listening to short scenarios about daily life situations via headphones, thinking about them in certain ways, and answering questions about them. We did not mention possible benefits for symptoms, nor mention that there were different conditions in the study. The only difference in instructions between conditions concerned the scenarios. Participants in CBM_ENH condition were told that they should listen to scenarios and try to vividly imagine themselves in the described situations, and focus particularly on the positive ending provided or one that they generated themselves. Participants in the CBM_RNT and control conditions were told to try and imagine themselves in the scenarios as they unfolded, and to try to anticipate the end of the scenarios.

¹¹ Please see Additional Supplemental Materials for details and results for these ratings. Overall, all participants expected the program to be moderately logical and useful prior to training, with no differences between CBM-I and control conditions. After completing the program, participants in the CBM-I conditions reported the program to have been more useful than did those in the control condition, though it did not influence how confident they felt in recommending the program; participants in CBM-I and control conditions felt moderately confident in recommending the program.

CONTROL). They then completed VAS mood ratings (ranging from 0 = *not at all* to 100 = *extremely*) indicating their current levels of anxiety, depression and happiness¹², before completing the first online session on the study website.¹³ Each online session included the RNT induction (CBM_ENH and CBM_RNT conditions) or neutral grammar task (CONTROL), followed by 40 or 50 scenarios (depending on condition, see above), with a short break after half of the scenarios. Following the first online session, participants completed context identification ratings about the scenario task, and CBM-I conditions also completed positive outcome identification ratings. Then participants completed the recognition test again¹⁴ and were given instructions to complete the online sessions at home.

Participants were encouraged to complete three sessions per week and were required to complete at least 8 online sessions within one month with the final session no later than the day before their second (post-training) visit. Researchers monitored adherence to the online sessions using the online platform. They kept in touch with participants by using participants' preferred methods of contact (email, phone, SMS) to facilitate engagement, trouble shoot issues, and encourage participants to catch-up with missed sessions.

Up to 24 hours before returning for their second visit, participants completed the questionnaires¹⁵ again, and an "adverse events form" for the period since the first session. Participants also completed acceptability ratings⁹, context identification ratings and – for CBM-I groups – positive outcome identification ratings. They then completed the scrambled sentences test, recognition test, worry and rumination tasks, before being debriefed in general

¹² Conditions did not differ for anxiety or depression ratings, but did differ for happiness ratings (ratings were lower in the CONTROL than in the two CBM-I conditions), though none of the pairwise comparisons reached statistical significance (see Supplemental Table 3 in Integral Supplemental Materials).

¹³ Participants were blind to their condition, but not experimenters, since they administered the imagery training (in the CBM_ENH condition) or filler tasks (CBM_RNT & CONTROL) and also guided participants through the first online session on the website, which differed by condition.

¹⁴ The second RT was not included as part of the current hypotheses and will not be reported here.

¹⁵ Except for the Spontaneous Use of Imagery Scale, which was only completed at baseline. See Footnote 8.

about the study. One month¹⁶ after their second study visit, participants again completed the standardized questionnaires, and the “adverse events form”. Participants received £130 (\$170) for their participation in the study. King’s College London ethics committee approved the study.

Plan of Statistical Analyses

As in Hirsch et al. (2018), participants were only viewed as ‘completers’ and included in analyses if they had completed at least 8 out of the 10 online sessions.

Assessing the impact of multi-session CBM-I and modulatory role of generation/imagery in CBM-I.

In keeping with Hirsch et al. (2018), we first compared both CBM-I conditions (combined) to the active control condition to examine the impact of multi-session CBM-I on interpretation bias, RNT, and mood outcome measures. To examine whether conditions differed in terms of identification with scenario context ratings (irrespective of the endings), they were first compared across combined CBM-I and CONTROL conditions. Then we compared the two active CBM-I conditions directly to determine whether the enhanced condition had greater effects on interpretation bias, RNT, and mood measures.

Below, we outline the analytic strategy for each of our outcome measures which follow a hypothesis testing approach used by Hirsch et al. (2018).

Interpretation bias. As in Hirsch et al. (2018), we conducted regression analyses (with bootstrapped standard errors in the case of non-normally distributed data) with mean score at the (post-training) second visit as the outcome variable and condition (combined CBM-I vs. control to address the impact of CBM-I; CBM_RNT vs. CBM_ENH to

¹⁶ The average time between visit 2 and completing the follow-up questionnaire was $M (SD) = 30.06 (4.28)$ days, indicating that the follow-up period was one-month, as intended.

address the modulatory role of positive outcome generation/imagery) as the predictor variable, and controlled for scores at the first visit (i.e., baseline scores).

Repetitive negative thinking. For RNT (RTQ-T), worry (PSWQ, PSWQ-pw) and rumination (RRS) questionnaires separately, we specified multi-level regression models with mean questionnaire score as the outcome variables and condition (see above), post-training time point (visit 2 and follow-up) as predictor variables, and controlled for mean score at visit 1. A random effect was included to account for the repeated assessment of the outcome variable within individuals.

For the worry and rumination tasks, we used the same analytic approach as for the interpretation bias measures. Specifically, we conducted regression analyses (with bootstrapped standard errors where appropriate) with mean number of negative intrusions / rumination score at (post-training) visit 2 as the outcome variable and condition (see above) as the predictor variable, and controlled for mean number of negative intrusions / rumination score at the first visit (i.e., baseline scores).

Anxiety and depression symptoms. For measures of anxiety and depression symptoms, we followed the same analytic strategy as that described above in relation to the questionnaire measures of RNT.

Assessing whether effects of CBM-I on RNT and mood were partially mediated by interpretation bias.

For exploratory purposes and akin to Hirsch et al. (2018), we examined whether change in interpretation bias partially mediated the effects of training on outcome measures that were significant at follow-up using structural equation modelling, following the product of coefficients approach. We specified models to test whether interpretation bias at visit 2 (analyses run separately for SST and RT) mediated the effects of condition (combined CBM-I vs. control) on worry (PSWQ, PSWQ weekly), rumination (RRS), RNT (RTQT), anxiety

(GAD-7), and depression (PHQ-9) scores at one-month follow-up (controlling for bias scores and symptom scores at visit 1). Bootstrapping with 1000 replications estimated the standard errors. The proportion of the effect explained by the indirect path was calculated.

Results

Descriptive Statistics

Descriptive statistics and model results for outcome measures by condition and time point are presented in Table 1.

[INSERT TABLE 1 HERE]

Effects of Multi-Session CBM-I Training vs. an Active Control Condition

Interpretation bias.

On the *Scrambled Sentences Test*, one participant was excluded from analyses because of a computer error at the second visit (resulting in no data at that time point), leaving 160 participants for this analysis. Condition (combined CBM-I vs. control) was significantly associated with positivity index at visit 2 (Hedges' $g = -.74$; see Table 1 for descriptive statistics and model results). As predicted, the combined CBM-I condition made more positive interpretations compared to the control condition following the online program. On the *Recognition Test*, one participant was missing data for visit 2 (technical error) and 7 participants were excluded due to poor task performance (scoring $< 2.5 SD$ below the mean for accuracy on the Recognition Test comprehension questions), leaving 153 participants for this analysis. Condition (combined CBM-I vs. control) was significantly associated with recognition test index at visit 2 (Hedges' $g = -1.24$; see Table 1). More positive (vs. negative) interpretations were made in the combined CBM-I condition compared to the control condition, as predicted. Thus, in line with our hypothesis, findings on both measures of

interpretation bias indicated that CBM-I led to a more positive interpretation bias than the control condition, and the size of the effect was moderate to large.

RNT tasks.

On the *worry task*, four participants were excluded from analyses due to technical problems with the task (e.g., a fire alarm sounding during the breathing focus period), leaving 157 participants for this analysis. Condition (combined CBM-I vs. control) was significantly associated with number of negative intrusions at visit 2 (Hedges' $g = .37$; see Table 1 for descriptives and model results). As expected, after controlling for negative intrusions at visit 1, participants in the combined CBM-I condition reported fewer negative intrusions compared to the control condition following completion of the online program.

On the *ruminative task*, one person was excluded because they were missing visit 1 data (due to a technical error), leaving 160 participants for this analysis. Condition (combined CBM-I vs. control) was not significantly associated with rumination ratings (Hedges' $g = .08$; see Table 1). Contrary to our hypothesis, there was no difference in level of state rumination between CBM-I and control conditions following the online program.

Self-report measures of repetitive negative thinking (RTQ-T), worry (PSWQ and PSWQ-pw) and rumination (RRS).

Five participants were excluded from analyses of all the self-report questionnaires because they reported commencing psychological treatment between visit 2 and follow-up ($n = 3$) or because they failed to complete the follow-up questionnaire ($n = 2$)¹⁷, leaving 156 participants for these analyses.

RTQ-T. CBM-I was associated with significantly lower trait repetitive negative thinking scores than the control condition at both visit 2 and importantly at follow-up (see Table 1;

¹⁷Two participants (1.2% of participants) completed training as well as Visit 1 and 2 assessments, but did not complete the follow-up measures. One showed slight improvement on most questionnaire scores over training, while the other showed slight deterioration. For example, PSWQ and RRS scores for one were 59 and 67 at Visit 1 and 62 and 68 at Visit 2, while for the other they were 74 and 71 at Visit 1 and 69 and 67 at Visit 2.

Hedges' $g_{\text{visit2}} = .42$, Hedges' $g_{\text{followup}} = .32$). Hence, as hypothesised, post-training repetitive negative thinking scores were lower in the CBM-I than the control condition at follow-up.

PSWQ. Contrary to our hypotheses, CBM-I was not associated with significantly lower trait worry scores than the control condition at either visit 2 or follow-up (see Table 1; Hedges' $g_{\text{visit2}} = .27$, Hedges' $g_{\text{followup}} = .22$).

PSWQ-pw. CBM-I was associated with significantly lower worry scores (over the past week) than the control condition at both visit 2 and follow-up (see Table 1; Hedges' $g_{\text{visit2}} = .35$, Hedges' $g_{\text{followup}} = .40$). Thus, in keeping with our hypothesis, post-training weekly worry scores were lower in the CBM-I than the control condition at follow-up.

RRS. Contrary to our hypotheses, CBM-I was not associated with significantly lower trait rumination scores than the control condition at either visit 2 or follow-up (Hedges' $g_{\text{visit2}} = .17$, Hedges' $g_{\text{followup}} = .10$).

Taken together, as predicted, the effects of CBM-I training (vs. control) were evident on a behavioural worry task post-training, and one-month later on self-reported levels of trait repetitive negative thinking and worry, though only for worry in the past week. However, there were no specific effects on rumination, either on the behavioural task or on the self-report, nor trait worry. Thus, our hypothesis was only partially supported.

Self-reported levels of anxiety (GAD-7) and depression (PHQ-9).

GAD-7. After controlling for baseline anxiety levels, CBM-I was associated with significantly lower anxiety scores than the control condition at follow-up, supporting our hypothesis, although not at visit 2 (Hedges' $g_{\text{visit2}} = .19$, Hedges' $g_{\text{followup}} = .36$).

PHQ-9. Similarly, CBM-I was associated with significantly lower depression scores than the control condition at follow-up but not visit 2 (Hedges' $g_{\text{visit2}} = .16$, Hedges' $g_{\text{followup}} = .30$), again supporting our hypothesis.

Overall, the findings provide partial support for the hypothesis that CBM-I – with and without imagery and self-generation of positive endings – would promote a more positive interpretation bias, reduce RNT, and improve mood in comparison with the control condition. Specifically, improvements were seen on interpretation bias, levels of worry on a behavioural measure and on self-report questionnaires in reference to the past week only (weekly PSWQ; i.e., not in regard to trait worry in general as measured by the PSWQ), levels of general RNT, as well as levels of anxiety and depression, relative to the active control condition. We did not find any beneficial effects of CBM-I vs. control on levels of rumination or trait worry.

Potential Modulatory Role of Self-Generation of Positive Resolutions to Ambiguity and Engaging in Positive Mental Imagery on the Effects of CBM-I Training

We examined whether vividly imagining the positive outcomes to the scenarios as well as generating one's own positive endings to the scenarios would increase the beneficial effects of CBM-I, that is, whether completing the enhanced CBM-I training (CBM_ENH) would lead to a more positive interpretation bias and greater reductions in worry, rumination, anxiety and depression symptoms relative to the CBM_RNT training.

As expected, interpretation bias scores post-training (controlling for pre-training scores) were higher in CBM_ENH condition than CBM_RNT condition for both the SST (Hedges' $g = -.52$) and the recognition test (Hedges' $g = -.54$), see Table 2, indicating that participants in CBM_ENH condition made more positive interpretations than participants in the CBM_RNT condition following three weeks of interpretation training. Furthermore, on the behavioural worry task measuring negative thought intrusions, participants in the CBM_ENH condition reported fewer negative intrusions post training (again controlling for baseline number of negative intrusions) than did participants in the CBM_RNT condition (Hedges' $g = .50$). No differences between CBM conditions were found for the rumination task (see Table 2).

Regarding the self-report measures, the only difference between CBM-I conditions was found on the measure of trait rumination (RRS) at follow-up: rumination scores at one-month follow-up (but not at visit 2) were lower in the CBM_ENH vs. CBM_RNT condition (Hedges' $g = .32$). There were no significant differences between CBM-I conditions for any of the other self-report measures. Thus, partially confirming our hypothesis, completing CBM_ENH training (compared to CBM_RNT) promoted a more positive interpretation bias and led to reductions in negative intrusions associated with worry, as well as trait rumination scores at one-month follow-up, but did not influence the rumination task post-training or self-reported trait RNT, worry, anxiety or depression at visit 2 or at one-month follow-up.

[INSERT TABLE 2 HERE]

Assessing Whether Interpretation Bias Post Training Partially Mediated Effects of CBM-I on Outcomes at Follow-Up

We also examined whether post training interpretation bias, assessed at visit 2, mediated the significant effects of condition (combined CBM-I vs. control) on outcome measures at one-month follow-up using structural equation modelling. Interpretation bias as measured by SST partially mediated the effect of CBM-I on anxiety and depression, though not worry in the past week or repetitive negative thinking generally (see Integral Supplemental Table 4 for all results). The indirect paths from condition to GAD-7 and PHQ-9 scores via SST visit 2 score were significant: the proportion of the effect mediated was .43 for GAD-7, and .58 for PHQ-9. Interpretation bias as measured by RT partially mediated the effect of CBM-I on repetitive negative thinking and depression (see Integral Supplemental Table 4 for all results). The indirect paths from condition to RTQ-T and PHQ-9 scores via RT visit 2 score were significant: the proportion of the effect mediated was .67, for RTQ-T, and .93 (i.e., nearly full mediation) for PHQ-9. Indirect paths from condition to PSWQ-pw ($p =$

.052) and GAD-7 ($p = .053$) via RT visit 2 score were at trend level; the proportion of the effect mediated was .51 for weekly PSWQ, and .56 for GAD-7.

Thus, .51 to .93 of the effect of condition (CBM-I vs Control) on follow-up questionnaire scores was mediated by level of interpretation bias (as measured by the SST and RT, separately) after completing the online program.

Self-identification ratings

Although the self-identification ratings on 1-7 scales were ad hoc and of unknown validity, they are reported here to assess participants' own perception of how much they felt they identified with the initial situations described in scenarios (irrespective of the final resolution). For the *context identification ratings*, as intended, there were no significant differences between the combined CBM-I and CONTROL conditions at either the first or second visit ($t(159) = -0.33, p = .745, d = -.05$; CBM-I: $M = 5.41, SD = .84$; control: $M = 5.46, SD = .97$ for session 1; $t(156) = -.31, p = .755, d = -.05$; CBM-I: $M = 5.25, SD = .93$; control: $M = 5.30, SD = 1.10$ for session 2). Thus, as we expected, participants from all conditions were able to identify with the main (non-ambiguous) context of the scenario context to a similar extent, with very small effect sizes for differences.

In contrast to the above *context identification ratings*, we expected that those in CBM_ENH condition should identify with the positive resolutions more than did those in the standard CBM condition. These participants did indeed provide higher *positive outcome identification ratings* than did those in the standard condition CBM-I following the first training session ($t(105) = 2.52, p = .013, d = .49$; CBM_ENH: $M = 4.89, SD = 1.05$; CBM_RNT: $M = 4.35, SD = 1.16$), although at visit 2 when ratings were completed in relation to all home-based sessions this difference did not reach significance and thus although the mean ratings was in the expected direction, there was insufficient evidence to

conclude a difference ($t(99) = 1.57, p = .12, d = .31$; CBM_ENH: $M = 4.98, SD = 1.00$; CBM_RNT: $M = 4.67, SD = .98$).

Discussion

In this experimental study¹⁸, we investigated whether a more positive interpretation bias could be trained in individuals with high levels of RNT, either worry and/or rumination, and if so whether this would lead to reductions in RNT and improvements in mood at one-month follow-up. As predicted, active training was associated with increased positive interpretations of ambiguity, and reduced RNT (as assessed by the RTQ-T, which was designed as a transdiagnostic measure of RNT), thus confirming our main hypothesis. More positive interpretations were evident across two measures of bias, indicating that training is effective in facilitating benign interpretations in people suffering from high levels of RNT and that, as hypothesized, this reduced trait RNT at follow-up.

Regarding more specific (diagnostically-linked) measures of worry and rumination, there was additional evidence of fewer negative thought intrusions in a behavioural worry task post-training. However, a questionnaire measure designed to assess one specific form of RNT, namely worry (PSWQ), revealed consistent changes only when rated in relation to the previous week, rather than in general. This differential effect suggests that self-observation of reduced worry (e.g., over the preceding week) does not immediately influence the individuals' perception of themselves as an excessive worrier (i.e., as a trait, or a person permanently prone to excessive worry). This result differs from that reported by Hirsch et al. (2018), who did find changes on the trait PSWQ following similar training in diagnosed

¹⁸ We want to make it clear that we regard this research is an experimental study of causal mechanisms underlying RNT rather than a clinical treatment trial, even if the results are taken to have implications for increasing treatment efficacy. We concur with Grafton et al. (2018) that it is inappropriate to designate all research that involves some form of modification as treatment trials, and that an experimental approach has utility in its own right to help identify treatment targets and pave the way for new interventions by investigating underlying mechanisms.

groups, but is similar to findings described by Grol et al. (2018) who, despite successfully training more positive interpretations¹⁹ in high worriers, did not find that training significantly influenced trait worry. Further research using longer follow-up durations may be required to determine whether, over time, the assessment of worry as a personal trait changes in line with current experience in individuals with high trait RNT.

Measures of rumination, using a general questionnaire, and a task that involved rating current (i.e., state) rumination about a past event, did not show a significant overall advantage due to training. It should be noted that the worry task involves assessing the number of negative thought intrusions when instructed to attend to breathing, whereas the rumination task involves rating statements about current thoughts and feelings about a past event that had just been described. Hence these two measures approach the assessment of the two forms of RNT very differently, and may vary in their sensitivity to change. It should also be noted that allocation to training materials depended on baseline scores on worry and rumination, leading to fewer participants being allocated to rumination-related training, so that the lack of overall significant effects on rumination may simply reflect reduced power. Finally, as will be discussed below, there was evidence of more change on rumination scores at follow-up in those allocated to the enhanced form of training compared with the standard condition, so that with more effective training, effects on rumination became more apparent.

Beyond changes in RNT, there was also support for the hypothesis that positive interpretation training would improve mood, since, as predicted, both anxiety and depression reduced more in the training groups than the control group at one-month follow-up. Mediation analysis indicated that interpretation bias change partially mediated these improvements in mood. Thus, extending the findings of Hirsch et al. (2018) in GAD and

¹⁹ Grol et al. (2018) used methods similar to our non-enhanced CBM condition, but participants did not engage in RNT prior to training sessions

clinically depressed individuals, it seems that negative interpretation bias may contribute to negative mood in a mixed population, selected as having high levels of RNT rather than by diagnosis.

A second aim of the study was to determine whether enhancing interpretation training with a combination of self-generation of positive outcomes and engaging in self-imagery would lead to greater change in interpretations and associated improvements in RNT and mood. Supporting the hypothesis, the enhanced condition was associated with greater positive change on both measures of interpretation bias: the scrambled sentence task (SST) and the recognition test. Unlike the recognition test, the SST is presented in a format quite distinct from that of the training materials, indicating some degree of near transfer. However, there was no evidence of generalization from this greater change on interpretations to measures of negative mood, although the enhanced condition did lead to fewer negative intrusions on the worry task post-training, and lower scores on the rumination questionnaire at one-month follow-up. It may seem surprising that rumination was reduced more by enhanced training in the absence of a parallel effect on rumination when comparing the combined training and control conditions. This suggests that the unenhanced (standard) form of interpretation training was relatively ineffective for changing rumination in this population, and that the focus on generating positive resolutions with self-imagery in the enhanced condition may be particularly relevant to modifying the negative self-focus characteristic of rumination.

Overall, the findings indicate that imagery and/or the self-generation of positive resolutions of ambiguity was indeed effective in enhancing training effects on interpretation, rumination and state worry (although not any greater reductions in anxiety and depression symptoms). These results are in contrast to Rohrbacher et al.'s (2014) single-session study, which did not find that self-generation enhanced training effects. One difference between the

studies is that Rohrbacher et al. (2014) involved an unselected sample, who were likely to have already had a positive interpretation bias, in contrast to those with high levels of RNT who tend to lack this positive bias (Krahé et al., 2019); self-generation of novel (positive) interpretations over a number of weeks may have been particularly helpful for individuals with high levels of RNT. Furthermore, Rohrbacher et al. (2014) required participants to generate endings on all trials, whereas the current study required it only 50% of the time. This combination of being provided with positive outcomes some of the time and then generating positive outcomes for the remainder may have been particularly helpful given the lack of a pre-existing positive bias in our population. Furthermore, participants in Rohrbacher et al. (2014) were required to report their imagined endings out loud; by not asking participants to speak their positive resolution, the current study may have reduced the cognitive effort required, and allowed participants to more fully immerse themselves in their positive imagery.

Furthermore, self-ratings of identification with positive resolutions showed an initial advantage for the enhanced condition (which may explain later augmentation of interpretation bias change), but there was insufficient evidence to conclude that CBM-I conditions differed in this respect over the whole course of training. However, findings from the identification ratings should be viewed with caution since the measure was developed for the study and has not been validated.

Furthermore, given the evidence that interpretation bias change partially mediated the effects on reduced depression symptoms in the combined training groups, it may seem surprising that the greater facilitation of positive interpretations in the enhanced condition did not transfer to mood measures. However, it seems likely that the lack of transfer of the augmented impact on interpretation bias evident in the enhanced CBM condition to mood

reflects the role of influences other than interpretation bias that continue to maintain negative emotion.

This study does not come without limitations. Because we did not conceive the study as a treatment trial, we did not pre-register it on a clinical trials registry. However, we realize that pre-registration is not only relevant for treatment trials and that this is a limitation of the current study. Further, in order to consider our findings in a non-diagnosed population in relation to Hirsch et al. (2018)'s findings in people with GAD or depression, we elected to use the identical 50 items per training session in the control and non-enhanced CBM conditions. However, the new enhanced condition required longer trials to enable self-generation of endings and imagery to be sustained for seven seconds. To equate overall session duration between conditions, only 40 trials per session were used in the enhanced condition. Furthermore, the explicit instructions in this enhanced condition were to generate positive images on all trials and positive endings (when required), leading to all 40 trials being positive, in contrast to only 38 (of 50 trials) in the non-enhanced training condition. Whilst it seems unlikely that in themselves the discrepancies between training conditions in overall trial number or proportion that were positive led to the differential change on interpretation bias, this cannot be ruled out. Moreover, we did not measure success of participant blinding, although participants were not explicitly told that there were different conditions (i.e., active vs. control). In addition, the current design cannot determine whether active generation or imagery components of the enhanced condition were both required to facilitate greater interpretation training. Future research could focus on resolving these issues. Nevertheless, the current data suggests that there is no inherent requirement for participants to be unaware that scenarios will end positively, given the findings for the enhanced vs. standard version of the CBM-I training. This may be useful to consider in relation to potential future clinical implementation and rationales given to participants in training conditions.

In the present study, we accepted participants on the basis of their reported level of worry or rumination, rather than a specific diagnosis such as GAD or Depression as in Hirsch et al. (2018). This led to some differences in the population of the two studies, specifically the present inclusion of some people unlikely to meet diagnostic criteria, as well as those with comorbid GAD and Depression (c.f. individuals with co-morbidity were excluded in Hirsch et al., 2018). Rather than conducting diagnostic interviews in the present study, we used a computerized program CAT-MH, which provides an estimate of the probability a person would meet diagnostic criteria for descriptive purposes, but without offering a definitive clinical diagnosis. Prior research has shown that there is no clear taxonomic division between RNT occurring in diagnosed and undiagnosed groups (e.g. Ruscio, Borkovec, & Ruscio, 2001) and the present research adds to these findings by showing that similar underlying processes (such as negative interpretation bias) contribute to RNT across groups not selected by diagnosis. This is not to deny that there may be surface features that differ across forms of RNT, such as a greater self-focus in rumination associated with Depression, as opposed to a focus on future threats in worry (occurring in both anxiety and depressive states). Nonetheless, we conclude that common cognitive processes underlie nominally diverse forms of RNT as evidenced by the finding that the same basic form of modification produced across the board improvements. Although in the present study this conclusion is supported only by evidence from modifying negative interpretative bias, future research could be directed towards modifying other putative common processes, to investigate their role in maintaining transdiagnostic forms of RNT that could guide future treatment developments. Furthermore, given that Cognitive Behavioral Therapy (CBT) often targets interpretations, and our enhanced training was particularly effective in this respect, future research could determine whether this new form of CBM-I could augment CBT outcome.

Acknowledgments

We are grateful to our steering committee members with lived experience of anxiety and depression for helping with the development of materials for the study, feedback on the tasks, design and research platform, to Emma Drinkwater-James for audio recording the study scenarios, to Amber Wood, Nafsika Christodoulidou and Alice Pisoni for their help with data collection and data entry. This work was supported by an MQ: Transforming Mental Health PsyIMPACT grant (number MQ14PP_84) to CH. CH receives salary support from the National Institute for Health Research (NIHR), Mental Health Biomedical Research Centre at South London and Maudsley NHS Foundation Trust and King's College London. The views expressed are those of the authors and not necessarily those of MQ: Transforming Mental Health, NHS, the National Institute for Health Research (NIHR), or the Department of Health. CK is now a lecturer at University of Liverpool.

Amber Wood

Alice Pisoni

References

- Baddeley, A. D., Emslie, H., & Nimmo-Smith, I. (1992). *Speed and Capacity of Language Processing Test*. Suffolk, England: Thames Valley Test Company.
- Barry, T. J., Hermans, D., Lenaert, B., Debeer, E., & Griffith, J. W. (2013). The eACS: Attentional control in the presence of emotion. *Personality and Individual Differences, 55*, 777-782.
- Basanovic, J., Notebaert, L., Grafton, B., Hirsch, C. R., & Clarke, P. J. (2017). Attentional control predicts change in bias in response to attentional bias modification. *Behaviour Research and Therapy, 99*, 47-56.
- Blackwell, S.E., Browning, M., Mathews, A., Pictet, A., Welch, J., . . . Holmes, E.A. (2015). Positive imagery-based cognitive bias modification as a web-based treatment tool for depressed adults: A randomized controlled trial. *Clinical Psychological Science, 3*, 91-111.
- Carlbring, P., Apelstrand, M., Sehlin, H., Amir, N., Rousseau, A., Hofmann, S. G., & Andersson, G. (2012). Internet-delivered attention bias modification training in individuals with social anxiety disorder-a double blind randomized controlled trial. *BMC Psychiatry, 12*, 66.
- Derryberry, D., & Reed, M. A. (2002). Anxiety-related attentional biases and their regulation by attentional control. *Journal of Abnormal Psychology, 111*, 225-236.
- Ehring, T., & Watkins, E. R. (2008). Repetitive negative thinking as a transdiagnostic process. *International Journal of Cognitive Therapy, 1*, 192-205.
- Gibbons, R. D., Weiss, D. J., Pilkonis, P. A., Frank, E., Moore, T., Kim, J. B., & Kupfer, D. J. (2012). Development of a computerized adaptive test for depression. *Archives of General Psychiatry, 69*, 1104-1112.

- Gibbons, R.D., Weiss, D.J., Pilkonis, P.A., Frank, E., Moore, T., Kim, J.B., & Kupfer, D. J. (2014). Development of the cat-anx: A computerized adaptive test for anxiety. *American Journal of Psychiatry, 171*, 187-194.
- Grafton, B., MacLeod, C., Rudazky, D., Holmes, E.A., Salemink, E., Fox, E., & Notebaert, L. (2018). Confusing procedures with process when appraising the impact of cognitive bias modification on emotional vulnerability. *British Journal of Psychiatry, 211*, 266-271.
- Grisham, J.R., Flower, K.N., Williams, A.D., & Moulds, M. L. (2011). Reappraisal and rumination during recall of a sad memory. *Cognitive Therapy and Research, 35*, 276-283.
- Grol, M., Schwenzfeier, A. K., Stricker, J., Booth, C., Temple-McCune, A., . . . Fox, E. (2018). The worrying mind in control: An investigation of adaptive working memory training and cognitive bias modification in worry-prone individuals. *Behaviour Research and Therapy, 103*, 1-11.
- Hayes, S., Hirsch, C., Krebs, G. & Mathews, A. (2010). The effects of modifying interpretation bias on worry in generalized anxiety disorder. *Behaviour Research & Therapy, 48*, 171-178.
- Hertel, P. T., Mor, N., Ferrari, C., Hunt, O., & Agrawal, N. (2014). Looking on the dark side: Rumination and cognitive-bias modification. *Clinical Psychological Science, 2*, 714-726.
- Hirsch, C. R., Hayes, S., & Mathews, A. (2009). Looking on the bright side: Accessing benign meanings reduces worry. *Journal of Abnormal Psychology, 118*, 44-54.
- Hirsch, C. R., Hayes, S., Mathews, A., Perman, G., & Borkovec, T. (2012). The extent and nature of imagery during worry and positive thinking in generalized anxiety disorder. *Journal of Abnormal Psychology, 121*, 238-243.

- Hirsch, C. R., Krahé, C., Whyte, J., Loizou, S., Bridge, L., Norton, S., & Mathews, A. (2018). Interpretation training to target repetitive negative thinking in Generalized Anxiety Disorder and Depression. *Journal of Consulting and Clinical Psychology, 86*, 1017-1030.
- Hirsch, C. R., & Mathews, A. (2012). A cognitive model of pathological worry. *Behaviour Research and Therapy, 50*, 636-646.
- Hirsch, C. R., Mathews, A., Lequertier, B., Perman, G., & Hayes, S. (2013). Characteristics of worry in generalized anxiety disorder. *Journal of Behavior Therapy and Experimental Psychiatry, 44*, 388-395.
- Hirsch, C. R., Meeten, F., Krahé, C., & Reeder, C. (2016). Resolving ambiguity in emotional disorders: The nature and role of interpretation biases. *Annual Review of Clinical Psychology, 12*, 281-305.
- Hirsch, C. R., Perman, G., Hayes, S., Eagleson, C., & Mathews, A. (2015). Delineating the role of negative verbal thinking in promoting worry, perceived threat, and anxiety. *Clinical Psychological Science, 23*, 637-647.
- Holmes, E. A., & Mathews, A. (2005). Mental imagery and emotion: A special relationship? *Emotion, 5*, 489-497.
- Holmes, E. A., Mathews, A., Dalgleish, T., & Mackintosh, B. (2006). Positive interpretation training: Effects of mental imagery versus verbal training on positive mood. *Behavior Therapy, 37*, 237-247.
- Hoppitt, L., Mathews, A., Yiend, J., & Mackintosh, B. (2010). Cognitive bias modification: The critical role of active training in modifying emotional responses. *Behavior Therapy, 41*, 73-81.

- Krahé, C., Whyte, J., Bridge, L., Loizou, S., & Hirsch, C. (in press). Are different forms of repetitive negative thinking associated with interpretation bias in generalized anxiety disorder and depression? *Clinical Psychological Science*.
- Kroenke, K., & Spitzer, R. L. (2002). The phq-9: A new depression diagnostic and severity measure. *Psychiatric Annals*, *32*, 509-515.
- Kuckertz, J. M., Gildebrant, E., Liliequist, B., Karlström, P., Väppling, C., Bodlund, O., . . . Amir, N. (2014). Moderation and mediation of the effect of attention training in social anxiety disorder. *Behaviour Research and Therapy*, *53*, 30-40.
- Marks, D. F. (1973). Visual imagery differences and eye movements in the recall of pictures. *Perception and Psychophysics*, *14*, 407-412.
- Mackintosh, B., Mathews, A., Yiend, J., Ridgeway, V., & Cook, E. (2006). Induced biases in emotion interpretation influence stress vulnerability and endure despite changes in context. *Behavior Therapy*, *37*, 209-222.
- Mathews, A., & Mackintosh, B. (2000). Induced emotional interpretation bias and anxiety. *Journal of Abnormal Psychology*, *109*, 602-615. Mathews, A., Ridgeway, V., Cook, E., & Yiend, J. (2007). Inducing a benign interpretational bias reduces trait anxiety. *Journal of Behavior Therapy and Experimental Psychiatry*, *38*, 225-236.
- Mathews, A., Ridgeway, V., & Holmes, E. A. (2013). Feels like the real thing: Imagery is both more realistic and emotional than verbal thought. *Cognition and Emotion*, *27*, 217-229.
- McEvoy, P., Tribodeau, M., & Asmundson, G. (2014). Trait repetitive negative thinking: A brief transdiagnostic assessment. *Journal of Experimental Psychopathology*, *5*, 382-398.
- Meyer, T. J., Miller, M. L., Metzger, R. L., & Borkovec, T. D. (1990). Development and validation of the penn state worry questionnaire. *Behaviour Research and Therapy*, *28*, 487-495.

- Nolen-Hoeksema, S., & Morrow, J. (1991). A prospective study of depression and posttraumatic stress symptoms after a natural disaster: The 1989 loma prieta earthquake. *Journal of Personality and Social Psychology, 61*, 115-121.
- Reisberg, D., Pearson, D. G., & Kosslyn, S. M. (2003). Intuitions and introspections about imagery: The role of imagery experience in shaping an investigator's theoretical views. *Applied Cognitive Psychology, 17*, 147-160.
- Rohrbacher, H., Blackwell, S. E., Holmes, E. A., & Reinecke, A. (2014). Optimizing the ingredients for imagery-based interpretation bias modification for depressed mood: Is self-generation more effective than imagination alone? *Journal of Affective Disorders, 152–154*, 212-218. doi:<http://dx.doi.org/10.1016/j.jad.2013.09.013>
- Rothbart, M. K., Ahadi, S. A., & Evans, D. E. (2000). Temperament and personality: Origins and outcomes. *Journal of Personality and Social Psychology, 78*, 122-135.
- Ruscio, A. M., Borkovec, T., & Ruscio, J. (2001). A taxometric investigation of the latent structure of worry. *Journal of Abnormal Psychology, 110*, 413-422.
- Spitzer, R. L., Kroenke, K., Williams, J. B., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: The gad-7. *Archives of Internal Medicine, 166*, 1092-1097.
- Standage, H., Harris, J., & Fox, E. (2014). The influence of social comparison on cognitive bias modification and emotional vulnerability. *Emotion, 14*, 170-179.
- Stoeber, J., & Bittencourt, J. (1998). Weekly assessment of worry: An adaptation of the penn state worry questionnaire for monitoring changes during treatment. *Behaviour Research and Therapy, 36*, 645-656.
- Stokes, C., & Hirsch, C. R. (2010). Engaging in imagery versus verbal processing of worry: Impact on negative intrusions in high worriers. *Behaviour Research and Therapy, 48*, 418-423.

- Watkins, E., R., & Moulds, M. L. (2007). Reduced concreteness of rumination in depression: A pilot study. *Personality and Individual Differences, 43*, 1386-1395.
- Watkins, E. R. (2008). Constructive and unconstructive repetitive thought. *Psychological Bulletin, 134*, 163–206.
- Wenzlaff, R., & Bates, D. (1998). Unmasking a cognitive vulnerability to depression: How lapses in mental control reveal depressive thinking. *Journal of Personality and Social Psychology, 75*, 1559-1571.
- Williams, M. O., Mathews, A., & Hirsch, C. R. (2014). Verbal worry facilitates attention to threat in high-worriers. *Journal of Behavior Therapy and Experimental Psychiatry, 45*, 8-14.

