The worrying mind in control: An investigation of adaptive working memory training and cognitive bias modification in worry-prone individuals

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ABSTRACT

Worry refers to the experience of uncontrollable negative thoughts. Cognitive models suggest that the combination of negative information processing biases along with diminished attentional control contribute to worry. In the current study we investigate whether promoting a) adaptive interpretation bias and b) efficient deployment of attentional control would influence the tendency to worry. Worry-prone individuals (*n* = 60) received either active cognitive bias modification for interpretation bias (CBM-I) combined with sham working memory training (WMT), adaptive WMT combined with sham CBM-I, or sham WMT combined with sham CBM-I. Neither of the active training conditions reduced worry during a breathing focus task relative to the control condition. However, when considering inter-individual differences in training-related improvements, we observed a relation between increases in positive interpretation bias and a decrease in negative intrusions. Moreover, increases in working memory performance were related to a reduction in reactivity of negative intrusions to a worry period. Our findings show that facilitating a more benign interpretation bias and improving working memory capacity can have beneficial effects in terms of worry, but also highlight that transfer related gains from existing training procedures can be dependent upon improvement levels on the training task.

1. Introduction

Worry is a form of repetitive thinking involving negative thoughts, typically about future events with uncertain or ambiguous outcomes, and is a hallmark cognitive characteristic of anxiety (Borkovec, Robinson, Pruzinsky, & DePree, 1983; Sibrava & Borkovec, 2006). Excessive worry about several topics is a prerequisite for a diagnosis of generalized anxiety disorder (GAD), while in other anxiety disorders worry is more focused on specific issues, e.g. worry about having a panic attack in panic disorder (American Psychiatric Association, 2013). Integrating basic research on the causal mechanisms underlying the tendency to worry is an important step towards exploring more sophisticated interventions targeting worry and anxiety.

Cognitive models of anxiety and worry have proposed that both automatic biases in the processing of emotional information and impairments in the control of attention can contribute to the cause and maintenance of pathological worry (Berggren & Derakshan, 2013; Hirsch & Mathews, 2012; Hirsch, Meeten, Krah, & Reeder, 2016). A

tendency to interpret ambiguous information in a more negative or threatening manner has been related to anxiety and worry (e.g. Eysenck, Mogg, May, Richards, & Mathews, 1991; Mathews & MacLeod, 2005; for a recent review see,; Hirsch et al., 2016). A number of methods have been developed that aim to modify this bias in interpretation - cognitive bias modification for interpretation (CBM-I) - which allows investigation of whether these biases have a causal effect on anxiety and worry. Grey and Mathews (2000), and Mathews and Mackintosh (2000) were the first to show that it is possible to modify interpretative bias in healthy individuals and that this can evoke changes in state anxiety according to the induced (positive or negative) interpretative bias.

A recent meta-analysis on the effectiveness of CBM-I (Menne-Lothmann et al., 2014) found that benign interpretation training had a large effect on post-training endorsement of positive versus negative interpretations. A small to medium effect was found for the change in interpretation bias across training, but this effect was increased by the use of feedback during training, use of imagery, and the number of

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training sessions. Benign interpretation training was the only condition to show a significant change in positive interpretation bias; however, this training effect (i.e. the degree of change in bias) was only significantly different from the change in bias caused by negative training but not as compared to control training (Menne-Lothmann et al., 2014). Furthermore, both benign and control training resulted in a small but significant reduction in negative mood.

Previous studies in worry-prone individuals (Hirsch, Hayes, & Mathews, 2009) and GAD patients (Hayes, Hirsch, Krebs, & Mathews, 2010) used a single-session interpretation bias training consisting of a combination of a homograph training task (Grey & Mathews, 2000) and an ambiguous scenario task. Auditory scenarios of emotionally ambiguous events were played to individuals. The scenario remained ambiguous up to the final word, which determined whether the scenario was either threatening or benign. A comprehension question was then presented to individuals for which the correct answer confirmed the provided outcome of the scenario (Hirsch et al., 2009). Feedback was used to reinforce the intended interpretation of the scenario. For the positive interpretation training condition, the scenarios were always resolved in a benign manner, while for the control training condition, the scenarios were resolved in a threatening manner half of the time and in a benign manner the other half. Individuals who received positive interpretation training, as compared to control training, reported fewer negative intrusive thoughts after training and experienced less anxiety during a task designed to assess the tendency to worry (Hayes et al., 2010; Hirsch et al., 2009).

Besides biases in the processing of emotional information, impairments in the control of attention are also believed to contribute to the cause and maintenance of worry (Berggren & Derakshan, 2013). Broadly speaking, attentional functions can be categorized into two systems, one subsystem that is involved in goal-directed, top-down selection, and a more stimulus-driven, bottom-up subsystem (Corbetta & Shulman, 2002). The Attentional Control Theory (ACT; Eysenck, Derakshan, Santos, & Calvo, 2007, p. 339) postulates that worry and anxiety "decreases the influence of the goal-directed attentional system and increases the influence of the stimulus-driven attentional system." Research shows that working memory capacity and other executive function tasks share an underlying component of executive attention (Mccabe, Roediger III, Mcdaniel, Balota, & Hambrick, 2010) and recent work demonstrates a strong link between attentional control and working memory (Shipstead, Lindsey, Marshall, & Engle, 2014). The efficiency of central executive functions of shifting between mental sets, updating and monitoring working memory content, and inhibition of irrelevant information (Miyake et al., 2000) are impaired by anxiety and worry, thus reducing attentional control (Berggren & Derakshan, 2013).

Several studies have shown that worry-prone individuals show processing efficiency related impairments on behavioural as well as neural measures requiring the efficient exercise of attentional control (Owens, Derakshan, & Richards, 2015; Sari, Koster, & Derakshan, 2016). Individual differences in propensity to worry have also been shown to impair the ability to inhibit irrelevant distractors (Fox, Dutton, Yates, Georgiou, & Mouchlianitis, 2015) and to inhibit threat-related distractors in an emotional version of a change detection working memory task (Stout, Shackman, Johnson, & Larson, 2015). A recent meta-analysis confirms there is a moderate and reliable association between anxiety and poorer performance on measures of working memory capacity (Moran, 2016). The development of cognitive training tasks has allowed investigators to further study the effects of facilitating working memory capacity. Working memory training has received a lot of attention but it remains a controversial topic. Several meta-analyses report mixed findings with some concluding working memory training does have benefits for cognitive skills and academic performance (Au et al., 2015) while others conclude working memory training does not improve performance (Melby-Lervåg, Redick, & Hulme, 2016). A recent systematic review (Koster, Hoorelbeke,

Onraedt, Owens, & Derakshan, 2017) examining the effects of cognitive control training on emotional vulnerability, reports that repeated training is a promising preventive intervention for a disorder like depression, notwithstanding that efficacy could be improved.

A frequently used training paradigm is the adaptive dual n-back task (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008, pp. 1–5) in which individuals are presented with two streams (visual and auditory) of information simultaneously. Participants are required to compare the visual and auditory information from the current trial with 'n' trials back (e.g. 2 trials back) and indicate whether there is a match. Importantly, the task becomes progressively more difficult with increases in performance, as the level of n increases (Jaeggi et al., 2008, pp. 1–5). Adaptive dual n-back training has shown to increase working memory capacity in dysphoric individuals, with training effects transferring to a change detection working memory task which requires the filtering of irrelevant distracting information (Owens, Koster, & Derakshan, 2013). An emotional version of the dual n-back task, with emotional faces as visual information and emotional words as auditory information, improved emotion regulation in response to negative film clips, both in terms of subjective levels of distress and in terms of an increase in activation in frontal brain areas involved in affective control (Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013). Sari, Koster, Pourtois, Derakshan (2016) found that the adaptive dual n-back training improved attentional control as measured by a Flanker task and as indicated by changes in resting state electroencephalography. Moreover, the degree of improvement on this neutral working memory training task correlated with greater reduction in self-reported trait anxiety across the training period (Sari, Koster, Pourtois, et al., 2016). A recent study found that a worry induction impaired working memory capacity and this was mediated by self-reported levels of state worry and anxiety (Sari et al., 2016). Taken together, these findings support the proposition that impaired attentional control is associated with anxiety and worry, and that worry itself further impairs attentional control, turning this into a cycle that maintains worry episodes.

Both impaired attentional control and the presence of negative emotional processing biases thus seem to be risk factors for pathological worry, and their interplay may be 'toxic' in terms of initiating and maintaining worry episodes (Hirsch & Mathews, 2012; see also; Eysenck et al., 2007). Hirsch and Mathews (2012) proposed that in worry-prone individuals, negative emotional processing biases can activate threat representations in response to external cues or internal reminders of threat. Such threat representations may compete for attention with currently activated information about ongoing tasks or benign topics, with the stronger or more active representation inhibiting the weaker representation. In worry-prone individuals the strength of negative emotional processing biases contributes to a greater activation of the threat representation, while at the same time impaired attentional control may be insufficient to maintain activation of task-related or benign representations (Hirsch & Mathews, 2012). The strongly activated threat representation is thus more likely to inhibit the currently activated task-related representation, resulting in distraction and the threat representation becoming stronger and intruding into awareness. Moreover, impaired attentional control then reduces the likelihood that attention is redirected to the intended (task-related or benign) representation, leading to a failure to control negative intrusions from developing into a worry episode (Berggren & Derakshan, 2013).

1.1. The current investigation

While both negative emotional processing biases (e.g. interpretation bias), and reduced attentional control resources have been shown to contribute to excessive worry, these two cognitive processes have typically been studied in isolation. However, based on cognitive models of anxiety and worry (Hirsch & Mathews, 2012) it seems that interpretation bias and attentional control contribute to excessive worry in a