



The effects of adaptive working memory training and mindfulness meditation training on processing efficiency and worry in high worriers[☆]



Jenna Course-Choi, Harry Saville, Nazanin Derakshan*

Department of Psychological Sciences, Birkbeck, University of London, Malet Street, London, WC1E 7HX, UK

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ABSTRACT

Worry is the principle characteristic of generalised anxiety disorder, and has been linked to deficient attentional control, a main function of working memory (WM). Adaptive WM training and mindfulness meditation practice (MMP) have both shown potential to increase attentional control. The present study hence investigates the individual and combined effects of MMP and a dual adaptive *n*-back task on a non-clinical, randomised sample of high worriers. 60 participants were tested before and after seven days of training. Assessment included self-report questionnaires, as well as performance tasks measuring attentional control and working memory capacity. Combined training resulted in continued reduction in worry in the week after training, highlighting the potential of utilising *n*-back training as an adjunct to established clinical treatment. Engagement with WM training correlated with immediate improvements in attentional control and resilience, with worry decreasing over time. Implications of these findings and suggestions for future research are discussed.

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1. Introduction

Worry has been defined as a stream of negative, uncontrollable thoughts and images that represent attempts to manage or avoid future threats and negative outcomes (Borkovec, Robinson, Pruzinsky, & DePree, 1983). Moderate levels of worry can be constructive, encouraging action against threatening or unpleasant stimuli (McCaul, Mullens, Romanek, Erickson, & Gatheridge, 2007) and facilitating problem solving (Szabo & Lovibond, 2002). However, excessive worry is an inefficient coping strategy (Borkovec, Hazlett, & Diaz, 1999) associated with depression and anxiety (Andrews & Borkovec, 1988; Starcevic, 1995), increased negative affect (Delgado et al., 2009) and impaired cognitive function (Hayes, Hirsch, & Mathews, 2008).

Worry has most often been studied in the context of generalised

anxiety disorder (GAD), of which it is considered to be a primary attribute (APA, 1994). Cognitive theories of both anxiety (Berggren & Derakshan, 2013; Derakshan & Eysenck, 2009; Eysenck, Derakshan, Santos, & Calvo, 2007) and depression (Joormann & D'Avanzato, 2010; De Raedt & Koster, 2010) posit deficits in attentional control are a central feature of anxiety and depression maintenance and recurrence. Attentional control has been defined as the efficiency with which we regulate attention towards relevant and away from irrelevant material, and is a key function of working memory (Duncan & Humphreys, 1989; Unsworth, Redick, Spillers, & Brewer, 2012). Attentional control is closely linked to the concept of working memory capacity (WMC) which according to recent research is the efficacy by which we attend to and maintain goal relevant information and resist distraction from task irrelevant material (Shipstead, Tyler & Engle, 2015). Recent conceptualisations go as far as to propose a causal role for attentional control in predicting anxiety and depressive-linked vulnerability (Sari, Koster, Pourtois & Derakshan, in press; Koster, Hoorelbeke, Onraedt, Owens & Derakshan, under review), with poor attentional control resulting in increased worry and rumination. It is thought the development of greater attentional control may therefore reduce anxiety and depression. Accordingly, and in line with studies suggesting plasticity of WMC and executive function (e.g. Klingberg,

[☆] Self-reported data collected pre- and post-training and at one-week follow up is included in Table 1 of Supplementary Information. Groups did not significantly differ at baseline on self-report measures, except for scores of rumination.

* Corresponding author. Centre for Risk and Resilience in Psychopathology, Department of Psychological Sciences, Birkbeck University of London, Malet Street, London, UK.

E-mail address: n.derakshan@bbk.ac.uk (N. Derakshan).

2010), there has been a burgeoning interest in the potential of cognitive training as a means to improve WMC and potentially alleviate clinical symptoms (e.g. Bomyea & Amir, 2011; Cohen, Mor, & Henik, 2015; Wanmaker, Geraerts, & Franken, 2015). We first summarise attentional control theory (Eysenck et al., 2007), upon which the study is based, and then review extant research of WM training and mindfulness meditation practice.

1.1. Attentional control theory

The central tenet of attentional control theory (ACT) is that anxiety impacts performance via its negative effects on attentional control. The exercise of attentional control involves the activation of two subsystems of attention: one top-down, goal-driven and controlled, the other bottom-up, stimulus-driven, and reflexive (Corbetta & Shulman, 2002). When these systems function effectively, goal-relevant information is selectively maintained and held readily available in WM, while irrelevant information is filtered so it does not distract. ACT holds that anxiety upsets the balance between these subsystems, reducing top-down processes through biasing increased bottom processes of attention (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). There is now substantial evidence showing an association between anxiety and an attentional bias for threat-related stimuli (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007, for a review) as well as evidence linking anxiety to inefficient recruitment of prefrontal mechanisms heavily implicated in attentional control (Ansari & Derakshan, 2011a, 2011b; Basten, Stelzel, & Fiebach, 2011, 2012). Both behavioural and neural evidence hence provide impetus for the assertion that anxiety heightens attention to task-irrelevant stimuli, leaving fewer resources available for concurrent task demands (see Berggren & Derakshan, 2013, for a review).

ACT suggests a possible mechanism by which anxiety reduces attentional control is through the impact of internal as well as external distractions – namely, negative self-dialogue or worry. Recent research has shown worry is associated with reduced cognitive control and fewer attentional control resources (Stefanopoulou, Hirsch, Hayes, Adlam, & Coker, 2014), and inefficient filtering of irrelevant information from WM (Stout, Shackman, Johnson, & Larson, 2014). Worry-linked vulnerability has been found to modulate the effects of cognitive control on cognitive load, necessitating greater use of cognitive resources to accomplish tasks involving heavy WM use (Owens, Derakshan, & Richards, 2015), with a recent study finding direct evidence for active worrying to reduce WMC (Sari et al., *in press*). Thus, reduced processing efficiency in worry is associated with a compensatory mechanism that necessitates the greater recruitment of prefrontal resources in achieving task outcomes, reducing attentional control. Elsewhere it has been documented that reduced attentional control may also maintain worry, directing resources towards worry thoughts in an attempt to manage a perceived threat (Hirsch & Mathews, 2012). Daches and Mor (2014) recently confirmed the effect of attentional control on excessive negative thought, demonstrating that a cognitive training protocol which promoted inhibition of irrelevant material resulted in a reduction of rumination. It seems high-worriers may become trapped in a cycle of cognitive impairment and negative bias not dissimilar to that identified in depressive rumination (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). It follows that increasing attentional control should improve cognitive efficiency and reduce worry.

1.2. Working memory training

One potential method for increasing attentional control is WM training, a relatively new mode of low intensity cognitive

treatment. The underlying mechanisms of WM training and transfer are still unclear (Buschkuhl, Jaeggi, & Jonides, 2012), but Engle and colleagues posit attentional control processes, including inhibition, modulate individual differences in WMC (Engle, 2002; Kane, Bleckley, Conway, & Engle, 2001). Inhibitory-related function has been shown to correlate highly with WMC in both healthy and dysphoric populations (Owens, Koster, & Derakshan, 2012; Vogel, McCollough, & Machizawa, 2005). Owens, Koster, and Derakshan (2013) therefore suggest WMC improvements following WM training are indicative of an underlying improvement to inhibitory processes, making such training a promising method for improving cognitive deficits associated with depression and anxiety.

One of the most commonly used WM training paradigms is the adaptive dual *n*-back training paradigm first employed by Jaeggi, Buschkuhl, Jonides, and Perrig (2008). It requires participants to process simultaneously-presented auditory and visual information and to determine whether either the current auditory or visual stimuli match those presented a specific number of trials (*n*) back in the sequence. After each sequence, the level of *n* increases, decreases or stays the same, depending on participant performance, so that as performance improves, the task becomes increasingly difficult. There is evidence linking *n*-back training to the improvement of a variety of executive processes, including focus of attention (Lilienthal, Tamez, Shelton, Myerson, & Hale, 2013), and filtering of irrelevant information in dysphoric individuals, with transfer to both behavioural and neural measures of WMC (Owens et al., 2013), but see Onraedt and Koster (2014) for failures of transfer-related gains of training on unrelated tasks, which contests to more research needed to establish the reliable transference of training-related gains to unrelated tasks. An affective version of the dual *n*-back task using emotionally valenced stimuli has been found to enhance WM and affective cognitive control (Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013). Other adaptive WM training has also been found to reduce depressive symptomatology in depressed samples (e.g. Brunoni et al., 2014), with long-term effects: Siegle et al. (2014) found a combination of treatment as usual and cognitive control training in a clinical sample resulted in reduced need for outpatient services one year later. These findings indicate targeting improvements in cognitive processes can lead to a reduction in depressive symptoms. Early research investigating the effects of such training in the context of anxiety is also promising. Sari et al. (*in press*) tested high trait anxious individuals before and after a three-week adaptive *n*-back training intervention, and found attentional control improved, with transfer to neural and behavioural measures. As yet, no current research has looked into sustained effects of inhibitory control post-treatment, a factor the current study investigates.

The clinical implications of such adaptive, systematic training are substantial - if WM training results in sustainable improvement in attentional control, it could complement existing treatments for anxiety and depression, including mindfulness-based and cognitive behavioural therapy. Online training programs such as the *n*-back task are low cost, easily accessible, and easily monitored. Surprisingly, however, no study of which the authors are aware has yet compared the effects of WM training against the effects of other interventions, or examined the potential of utilising WM training as an adjunct to established clinical treatment. Could mindfulness practice, another form of training thought to utilise and increase attentional control, stand to benefit from the effects of WM training?

1.3. Mindfulness training

Over the past 20 years, clinicians have increasingly incorporated

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