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A randomised controlled trial investigating the benefits of adaptive working memory training for working memory capacity and attentional control in high worriers

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ABSTRACT

The process of worry has been associated with reductions in working memory capacity and availability of resources necessary for efficient attentional control. This, in turn, can lead to escalating worry. Recent investigations into working memory training have shown improvements in attentional control and cognitive performance in high trait-anxious individuals and individuals with sub-clinical depression. The current randomised controlled trial investigated the effects of 15 days of adaptive *n*-back working memory training, or an active control task, on working memory capacity, attentional control and worry in a sample of high worriers. Pre-training, post-training and one-month follow-up measures of working memory capacity were assessed using a Change Detection task, while a Flanker task was used to assess attentional control. A breathing focus task was used as a behavioural measure of worry in addition to a number of self-report assessments of worry and anxiety. Overall there was no difference between the active training and the active control condition with both groups demonstrating similar improvements in working memory capacity and worry, post-training and at follow-up. However, training-related improvements on the *n*-back task were associated with gains in working memory capacity and reductions in worry symptoms in the active training condition. These results highlight the need for further research investigating the role of individual differences in working memory training.

1. Introduction

Worry is defined as “the repeated experience of apparently uncontrollable thoughts regarding future negative events” (Hayes, Hirsch, & Mathews, 2008, p. 3). It occurs on a continuum, with generalised anxiety disorder (GAD) falling at the more severe end (American Psychiatric Association, 2013). GAD affects an estimated 4.4% of people in England (McManus, Meltzer, Brugha, Bebbington, & Jenkins, 2009), while 6.2% of the adult population of the United States of America will also experience GAD during their lifetime (Kessler, Petukhova, Sampson, Zaslavsky, & Wittchen, 2012). This results in severe disability or limitations to usual activities for 42% of sufferers (Sanderson & Andrews, 2002). Within the United Kingdom, treatment guidelines recommend Cognitive Behavioural Therapy or selective serotonin reuptake inhibitors for individuals with marked

functional impairment as a result of significant worry (National Institute for Health and Care Excellence, 2011).

Worry can have a disruptive influence on major cognitive functions, including working memory, which play a crucial role in every day functioning. It has been suggested that worry acts as an internal distracter, attracting attention away from a current task, and thus reducing the capacity for attentional control (Hirsch & Mathews, 2012). Working memory capacity (WMC), a concept that is closely related to attentional control (Shipstead, Lindsey, Marshall, & Engle, 2014), reflects “the efficacy by which goal relevant information is attended, stored, and maintained while task irrelevant information is suppressed” (Sari, Koster, & Derakshan, 2017, p. 2.). When WMC is reduced, attentional control is also affected, since an individual has fewer resources accessible for voluntary, top-down control of attention towards current task demands (Hirsch & Mathews, 2012). For instance, trait vulnerability to

Abbreviations: CBT, Cognitive Behavioural Therapy; FMPS, Frost Multidimensional Perfectionism Scale; GAD, Generalised Anxiety Disorder; MINI, Mini International Neuropsychiatric Interview; NART, National Adult Reading Test; PSWQ, Penn State Worry Questionnaire; STAI-TA, Spielberger Trait Anxiety Inventory; WDQ, Worry Domains Questionnaire; WMC, working memory capacity; WMT, working memory training

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worry (Owens, Derakshan, & Richards, 2015) as well as an episode of active worrying (Sari et al., 2017) can reduce WMC, affecting major executive functions such as inhibition of irrelevant material, leading to the inefficient processing of relevant information.

In support of this perspective, worry-prone individuals have been shown to perform less well on tasks requiring attentional control. Stout, Shackman, Johnson, and Larson (2015), for instance, found that individual differences in subjective worry are associated with difficulties gating threat distracters from working memory during a change detection task. Moreover, once threat-related information is in working memory, it biases attention, even if the threat is no longer present. This mechanism produces a vicious cycle leading to escalating levels of worry. Further evidence comes from the observation that individuals with (pre-existing) limited attentional control resources, as reported on a self-report scale, are particularly vulnerable to bias towards threat, as indicated by difficulties disengaging from threatening information during a simple detection task (Derryberry & Reed, 2002). Moreover, Stefanopoulou, Hirsch, Hayes, Adlam, and Coker (2014) invited participants to complete a random key-pressing task while thinking about a worrisome event and observed that worry consumed more attentional control resources in individuals with GAD than in control participants, as indicated by a decrease in the proportion of random key presses by participants with GAD (but not controls) when thinking about a worrying event, compared to a positive event. Stefanopoulou et al. also demonstrated that people with GAD had greater difficulty than controls in sustaining attention when demands on attentional control were increased during a *n*-back task. These results largely replicated those found by Hayes et al. (2008) who had also used a random key-press task to demonstrate that high worriers show more restricted WMC, and hence fewer attentional resources, when thinking about a current worry than when thinking about a positive topic, an effect not found in low worriers. Similarly, Sari et al. (2017) found that compared to a non-worry control condition, students undergoing a period of active worry demonstrated impaired WMC, and this effect was mediated by self-reported worry.

A recent meta-analysis (Moran, 2016) has confirmed the consistent link between anxiety or worry and limitations in WMC, and how the combination of high worry and low WMC, appears to reduce the cognitive resources available for attentional control. This body of work leads to the suggestion that it may be valuable to train WMC in high worriers. By training WMC, the efficiency of attentional control is likely to increase, which should in turn reduce worry, as there will be more mental resources available to exert cognitive control over whether negative thoughts attract attention.

One issue associated with many of the studies discussed above is the subjective nature of the measurements used to assess worry. Such methods are often susceptible to bias themselves and therefore it is useful to also obtain a more objective measure of worry. A widely-used method was introduced by Borkovec, Robinson, Pruzinsky, and DePree (1983) that involves an assessment of participants' ability to focus on their breathing before and after a time-period of worrying. An adaptation of this task was used by Fox, Dutton, Yates, Georgiou, and Mouchlianitis (2015) to assess the effectiveness of a cognitive training procedure designed to improve attentional control on the reduction of worry. Although the cognitive training procedure (based on the flanker task) was largely ineffective, they found that improvements in attentional control were associated with participants' ability to suppress worry-related thought intrusions during a breathing-focus task similar to that used by Borkovec et al. Such findings highlight the value of including both subjective and objective measures of worry during the assessment of interventions targeting a reduction in worry.

A growing body of research is investigating whether it is possible to train WMC. For example, Jaeggi, Buschkuhl, Jonides, and Perrig (2008) successfully used an adaptive dual *n*-back task to train the WMC of healthy participants. In the dual *n*-back task, participants are required to make a decision about whether paired visual and auditory stimuli match those presented *n* trials back, with difficulty increasing

up to the 4-back level. Task difficulty is adjusted relative to task performance, thus providing adaptive training, and resulting in load on working memory gradually increasing over time. Jaeggi et al. found that, compared to a non-adaptive control condition, as few as 17 days of training using the dual *n*-back task led to improvements in both WMC and fluid intelligence, as measured by the Bochumer Matrizen-Test. Importantly, this test was entirely unrelated to the *n*-back task, indicating a transfer of training effects. Despite findings such as that by Jaeggi et al., there is still much debate about the effectiveness of working memory training. Indeed, in a meta-analytic review of 87 publications reporting on the impact of WMT on a variety of cognitive functions, Melby-Lervåg, Redick, and Hulme (2016) concluded that, while there was evidence for improvements on near transfer tasks (e.g., verbal and visuospatial working memory), there was no evidence for far-transfer to other cognitive abilities such as reading comprehension, mathematical ability, or general measures of verbal or nonverbal ability. This extensive review did not, however, consider the potential benefits of WMT in emotionally vulnerable populations.

There has been much recent debate about the potential benefits of adaptive working memory training (WMT) in emotionally vulnerable populations, such as those with depression or anxiety (see Keshavan, Vinogradov, Rumsey, Sherrill, & Wagner, 2014; Koster, Hoorelbeke, Onraedt, Owens, & Derakshan, 2017; Motter et al., 2016 for discussion). To illustrate, Owens, Koster, and Derakshan (2013) found that, compared to a non-adaptive training control group using a 1-back version of WMT, eight days of adaptive working memory training on the dual *n*-back task led to training related gains in WMC, as measured by a change-detection task and these gains correlated with improvements in inhibitory function as measured by electroencephalography (EEG). In a follow-up study, high trait anxious participants were randomly assigned to 15 sessions of adaptive dual *n*-back or non-adaptive dual 1-back training (Sari, Koster, Pourtois, & Derakshan, 2016). The three weeks of adaptive training led to significant improvements in attentional control, as measured by a Flanker task and resting state EEG, and these gains were associated with a reduction in trait anxiety. Furthermore, Sari et al. (2016) observed that the level of improvement on the *n*-back task was significantly associated with reductions in anxiety symptomology. This indicates that the degree of engagement with the training task may predict the extent to which training leads to far-transfer improvements on emotional domains, such as anxiety.

Hadwin and Richards (2016) investigated the effects of WMT in children who reported elevated anxiety and reduced attentional control. Elevated anxiety was indicated by a score above the average population norm on the Spence Children's Anxiety Scale (Spence, 1998), while reduced attentional control was signified by a below median score on the attention subscale of the Early Adolescent Temperament Questionnaire Revised (Ellis & Rothbart, 2001). Thirty-six participants aged eleven-to-fourteen years were randomly allocated to an adaptive WMT group or an active cognitive behavioural therapy (CBT) control group. Children in the adaptive group completed twenty-five sessions of WMT, over a period of five weeks, while the control group involved ten bi-weekly 1-h sessions of group CBT, also over a period of five weeks. Hadwin and Richards found that both interventions were equally effective at reducing anxiety symptoms, increasing inhibitory control and reducing attentional biases to threat. These improvements were maintained at three-month follow-up. Since WMT does not require regular sessions with a therapist, it has the potential to be a cost-effective alternative, or adjunct to CBT, suggestion that WMT may be a plausible low-level intervention for protecting against the development of clinical anxiety in at risk individuals.¹

¹ More recently, research has indicated that rather than using a dual *n*-back training task focusing on both visual and verbal working memory, a single visual *n*-back WMT task are equally effective at training working memory (Jaeggi et al., 2010), meaning that simpler *n*-back training paradigms may lead to equivalent outcomes.

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