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

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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.

Keywords: Attentional Control, Worry, Working Memory Training

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, Pruzinksy, & 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, & Matthews, 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 (Eysenck, Derakshan, Santos, & Calvo, 2007; Derakshan & Eysenck, 2009; Berggren & Derakshan, 2013) 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 et al., 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, 2016; 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, 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.

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 et al., 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 Ijezendoorn, 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 et al., 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 (Beckwe, Derrost, Koster, De Lissnyder, & de Raedt, 2014), 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, Koster, Pourtois, & Derakshan, 2016). 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 & Matthews, 2012). Daches and Mor (2013) 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.

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 (Buschkuehl, 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 (Vogel et al., 2005; Owens, Koster, & Derakshan, 2012). 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, Buschkuehl, 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, Koster, Pourtois and Derakshan (2016) 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?

Mindfulness training

Over the past 20 years, clinicians have increasingly incorporated mindfulness-based interventions into treatment, and there is substantial evidence of its beneficial impact on a wide range of psychological disorders, including chronic pain (Kabat-Zinn, 1984), substance abuse (Marlatt, 1994), and anxiety and depressive symptoms (Coehlo, Canter, & Ernst, 2007; Kim et al., 2009; for meta-analyses see Baer, 2003; Grossman, Niemann, Schmidt, & Walach, 2004). Described as "paying attention in a particular way, on purpose, in the present moment, and nonjudgmentally" (Kabat-Zinn, 1994, p.4), its concept is rooted in Buddhist philosophy, which suggests the state of mindfulness is developed through meditation practice. Mindfulness meditation practice (MMP) focuses attention on the sensations of the breath and the body, fostering passive observation of internal and external phenomena (Wallace & Shapiro, 2006). Operational definitions of mindfulness have produced conflicting conceptualisations (e.g. Bishop et al., 2004; Baer, Smith, & Allen, 2004; Lau et al., 2006), but the two facets emphasised by most are nonjudgment of, and complete attention to, the present moment. In this latter aspect, a fundamental component of MMP is attentional training. Bishop et al. posit clinical benefits associated with MMP, such as reductions in rumination and avoidance (Kumar, Feldman, & Hayes, 2008), may be linked to improvements in attentional control and the inhibition of unnecessary elaborative processing. Several processes have been proposed to account for this. Accepting, rather than judging, thought processes could disengage typical cognitive biases and defences. This may increase cognitive flexibility (Roemer & Orsillo, 2003) and reduce reactivity to negative emotions (Baer, 2003). MMP may also promote emotional stability through its emphasis of non-judgemental observation of present-moment phenomena, without avoidance or over-involvement (Carmody, 2009). Delgado et al. assert these processes "are clearly opposite to those of chronic worry" (2010, p. 874), and could therefore act as a mechanism to counter it.

Studies measuring MMP's effect on self-reported anxiety and depressive symptoms support these theories (Evans et al., 2008; Segal, Williams, & Teasdale, 2002). MMP training has been shown to reduce self-reported worry in older adults (Lenze et al., 2014) and physiological measures of worry in non-clinical high worriers (Delgado et al., 2010). Self-reported depressive rumination has been reduced in healthy participants after a 10-day MMP retreat (Chambers et al, 2008), while just four or five 20-minute MMP sessions have produced a significant drop in anxiety (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010; Tang et al., 2007). Reductions in affective disorder symptomatology also appear to sustain after treatment has finished (Baer, 2003), with improvements remaining intact three months post-treatment (Kabat-Zinn et al, 1992; Miller et al, 1995).

However, research investigating cognitive effects of MMP thought to mediate the above results suggests length of meditation practice is key. An association between long-term MMP and various aspects of attention has been documented, including sustained attention (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007; Jha, Krompinger, & Baine, 2007), enhanced attention switching (Hodgins & Adair, 2010), selective attention and executive attention (Chan & Woollacott, 2007). Yet studies of briefer interventions have been mixed, with many failing to observe group differences on these measures post-intervention (Anderson, Lau, Segal, & Bishop, 2007; Polak, 2010; Tang et al., 2007). Short-term MMP interventions measuring effects on WMC have also produced conflicting findings, some reporting significant WMC improvements (Mrazek, Franklin, Philips, Baird & Schooler, 2013), others yielding mixed results (Zeidan et al., 2010). The possibility that WM training might boost the efficacy of short-term MMP, or act as a catalyst by promoting attentional control processes, is an exciting prospect for proponents of MMP.

The current study

Although a combination of cognitive training and pharmaceutical treatments has proven fruitful (Siegle et al., 2014), the present study is the first to investigate the effects of WM training in conjunction with another low intensity intervention believed to affect the same cognitive mechanisms. The study aims to examine the individual and combined effects of a well-established form of WM training and MMP on attentional control/WMC and negative symptomatology in a population of high worriers. Previous MMP studies have often featured non-randomised designs (e.g. Jha et al., 2007; for a review, see Chiesa, Calati, & Serretti. 2011), while studies of WM training have produced conflicting results (e.g. Borella, Carretti, Riboldi, & De Beni, 2010; Chein & Morrison, 2010), leading some to question its efficacy and transferability (see Shipstead, Redick, & Engle, 2012). The present study is randomised with an active control, aiming to produce robust findings. We also wanted to consider the importance of magnitude of progress during WM training as a potential mechanism underlying WM training transfer. Training improvement is not always taken into account (e.g. Brehmer, Westerberg, & Backman, 2012), but was highlighted in von Bastian and Oberauer's (2014) recent review of training studies as an important consideration that future research should take into account. Evidence for this has begun to surface in the literature – Sari et al. (2016) found training-related gains were associated with reductions in self-reported levels of trait anxiety – and will be further examined here.

Here, we investigated the effects of seven days' training comprising one of the following regimes: 1) a non-adaptive dual 1-back task, which served as an active control, 2) WM training, in the form of an adaptive dual *n*-back task, 3) MMP, in the form of a guided sitting meditation, and 4) combined adaptive dual *n*-back task and guided sitting meditation. The neutral dual n-back task (as in Owens et al. 2013; Sari et al. 2016) was used. The choice for seven days of continuous training was motivated by previous research showing reliable transfer effects with similar (e.g. Owens et al. 2013), or much shorter lengths (e.g. Siegle et al. 2014). Self-report measures pre- and post-training were used to investigate effects on emotional vulnerability and resilience. As very little research includes resilience-related measures to examine transfer of cognitive-related benefits it was decided to include a measure of resilience in the current study. These measures were also administered one week after training, to examine longer-term effects of training after consolidation with the environment. Transfer of training-related gains on cognitive performance was examined using the antisaccade task, a process-pure measure of attentional control measuring inhibition (see Friedman & Miyake, 2004) and a visual change detection task (CDT) measuring WMC. The antisaccade task (Hallet, 1978) is a widely used measure of attentional control in healthy individuals (Hutton & Ettinger, 2006) as well as clinical and subclinical anxiety and depression (see Ainsworth & Garner, 2013; Berggren & Derakshan, 2013, for reviews). Successful performance on this task requires top-down attentional control for the inhibition of a reflexive saccade towards a sudden peripheral stimulus, while at the same time executing a voluntary saccade in the opposite direction as quickly as possible. Correct antisaccade latencies index processing efficiency, as slower reaction times are believed to reflect the utilisation of greater processing resources to inhibit reflexive saccades towards the stimulus (Olk & Kingstone, 2003). The effect of anxiety on antisaccade latencies has been confirmed repeatedly (see Berggren & Derakshan, 2013).

The CDT is a standard paradigm for measuring visual WMC, which in this task is positively correlated with the ability to filter task-irrelevant information from WM (Vogel et al., 2005; Owens et al., 2012, 2013). Previous research has found that depressive vulnerability (Owens et al., 2012, 2013) is linked with poor WMC and active worrying reduces WMC (Sari et al., 2016) as assessed by the CDT task. The CDT was the same used in Owens et al. (2012, 2013), and Sari et al. (2016).

In line with previous research (Owens et al., 2013; Sari et al., 2016), we predicted participants who undertook WM training would show improvement in WM performance over the training period with transferable gains on self-reported worry, as well as other measures of emotional vulnerability and resilience, and cognitive performance, relative to the control group. We also predicted that these changes should be greater with combined WM training and MMP, relative to the group who undertook mindfulness training alone.

Method

Participants

A sample of high worriers was recruited via advertisements on the campus of Birkbeck, University of London, as well as online. Participants were offered £20, or course credits, for their participation for approximately 5 experimental hours. Participants had to be over the age of 17, and were preselected based on their scores on the Pennsylvania State Worry Questionnaire (PSWQ;

Meyer, Miller, Metzger, & Borkovec, 1990). Participants with PSWQ scores of 45 or more were eligible for the study (National IAPT Programme Team, 2011). Of a total of 86 individuals invited to participate, 18 were excluded due to no response or unavailability, 4 because they did not complete enough training sessions, 2 because they requested to be withdrawn after the first testing session, 1 due to technical failures, and 1 due to a lower PSWQ score (<45) at time of pre-intervention.

A final sample of 60 participants (15 male) with normal or corrected-to-normal vision was analysed. Participants were randomly assigned to one of the four training conditions at baseline (after exclusion criteria were considered) resulting in 15 participants in each group. A sample size of 15 in each group is compatible with previous research using similar group sizes yielding moderate to high effect size (e.g. Owens et al. 2013; Sari et al., 2016). Groups did not significantly differ from each other on age (Control, $M = 27.33$, $SD = 3.96$; *N*-back, $M = 27.93$, $SD = 7.29$; MMP, $M = 30.67$, $SD = 8.91$; Combined, $M = 28.73$, $SD = 9.48$; Welch's $F(3,29) < 1$), and had a similar gender distribution, (Control, 3 males-12 females; *N*-back, 5 males-10 females; MMP, 4 males-11 females, Combined, 3 males-12 females; $p = .91$, two-tailed Fisher's exact test). Groups did not significantly differ from each other on the pre-selection measure of PSWQ scores at pre-test, (Control, $M = 55.80$, $SD = 11.30$; N-back, $M = 55.87$, $SD = 8.53$; MMP, $M = 61.73$, $SD = 7.15$; Combined, $M = 56.93$, $SD = 5.89$; $F(3,56) = 1.66$, *ns*). The study was approved by Birkbeck's ethical committee.

Materials and Tasks

Self-report measures. At pre-intervention, participants completed self-report measures of state anxiety (STAI-SA; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), resilience (Connor-Davidson Resilience Scale [CD-RISC]; Connor & Davidson, 2003), rumination (Ruminative Response Scale [RRS]; Nolen-Hoeksema & Morrow, 1991) and current mood (Positive And Negative Affect Schedule [PANAS]; Watson, Clark, & Tellegen, 1988). Baseline PSWQ scores were taken from screening, unless the screening survey was completed over one calendar month prior to the first session. In such cases, the PSWQ was re-administered alongside the other questionnaires (10 participants).[1]

Anti-saccade and Pro-saccade tasks. This was modelled on Derakshan et al., 2009 (Exp1). Eye-movements were recorded using an SR Research Eyelink 1000 eye-tracker (SR Research, ON, Canada). Only one eye was tracked during the experiment. Calibration involved tracking nine points across the computer screen to ensure tracking accuracy was within 1° of visual angle. Images were presented on a 21″ Mitsubishi Diamond Pro 2070 CRT monitor (85 Hz) and a chinrest was used to ensure a constant viewing distance of 60 cm. The experiment was designed and presented using the SR Research Experiment Builder software. The stimulus used for the antisaccade and prosaccade tasks consisted of a white oval-shaped object (created in simple graphics design application) subtending 2.58° × 4.77° and measuring 35 x 63 mm in dimension, presented on a black background. This oval shape served as a ‘‘Target’’.

Each trial started with a fixation cross subtending 0.95° × 0.95° and measuring 12 x12 mm presented in the center of the screen for 1000ms. Participants were instructed to fixate on the cross until it disappeared. After a short gap (200ms), the stimulus (the white oval-shaped object) was presented 11° from the centre of the screen, for 600ms, either to the left or right along the horizontal axis, with equal probability. Participants were required to direct their gaze as quickly as possible either “AT” the cue (prosaccade task) or “AWAY FROM” the cue (antisaccade task), before returning to the fixation cross, which reappeared at the start of the next trial. There were four experimental blocks (two antisaccade and two prosaccade) of 36 trials, resulting in a total of 144 trials. Block order was counterbalanced between participants.

Change detection task. This task was adapted from Owens et al. (2012, 2013) and programmed in E-prime. Stimuli were shown on a 17” monitor. Participants were positioned 60cm from the monitor and instructed to focus on a central fixation cross throughout the task. Trials began with a white arrow shown above the fixation, pointing left or right and presented for 700ms. Participants were instructed to attend to the side the arrow pointed to. Two arrays were then shown in quick succession, featuring a combination of red (target) and blue (distractor) rectangles on both sides of the fixation. Participants were required to remember the orientation of red rectangles on the side the arrow had pointed towards in the first array, and to compare it to the second array, which was presented after a 900ms retention gap. During the presentation of the second array, participants recorded whether the orientation of any of the target red rectangles was altered or whether they remained identical by pressing one of two keys.

There were three array conditions: on both sides of the fixation, each array featured either two red rectangles, four red rectangles, or two red rectangles and two blue rectangles. The first array was presented for 100ms. Stimuli disappeared for 900ms before the second array was presented for 2000ms. In half the trials, no change in the orientation of any rectangles occurred. In the other half, the orientation of one red rectangle differed between the two arrays. Rectangles were oriented randomly and were either vertical, horizontal, 45 degrees left or 45 degrees right. Array condition, arrow direction and change or no-change trials were randomised. Participants' responses were recorded.

Adaptive dual n-back training task. The dual *n*-back task was similar to that of Owens et al. (2013). Participants were presented with a 3 x 3 grid of nine squares. A fixation cross occupied the central cell. In each trial, one of the remaining eight cells turned green. Simultaneously, one of eight letters (c, h, k, l, q, r, s, t) was spoken by a female automated voice. Participants were instructed to remember both the letter spoken and the location of the green square and to compare the current letter/location to that presented *n* number of trials back in the sequence. If there was a letter match, they were asked to respond by pressing the "L" key. If there was a location match, they were asked to respond by pressing the "A" key. Where both letter and location matched, participants were able to press either or both keys, and for no match, no response was necessary. Trials lasted 3000ms each (500ms stimuli presentation, 2500ms inter-stimuli interval). Participants in the *n*-back training group completed 20 blocks, each comprising 20 + *n* number of trials, while participants in the combined training group completed 15 blocks. The training adapted to the level of the participant, with the level of *n* increasing when a participant achieved over 95% accuracy averaged across audio and visual conditions, maintaining when response accuracy was between 95% and 75%, and decreasing when response accuracy was below 75%. Level of '*n*' could increase to a maximum of 4-back. Each block contained matches for four letters, four locations, and two both, randomly distributed within the block. Blocks were separated by short breaks of 20 seconds.

Control 1-back task. As in Owens et al. (2013), the control group completed a *1*-back version of the task, identical in length and design to that of the *n*-back group, but without the adaptive function: participants only ever had to compare the stimuli to what was presented in the previous trial, regardless of performance level.

Mindfulness audio. The audio clip used was from The Free Mindfulness Project, an online collaboration providing access to mindfulness meditation exercises. The clip is free to download and distribute non-commercially. The audio clip was a guided seated meditation session lasting 21:03 minutes from the UCSD Center For Mindfulness, a program of the UC San Diego Center for Integrative Medicine and Department of Psychiatry, which promotes mindfulness-based techniques and initiatives. As is typical with seated meditations, the central focus of the session is the breath. Awareness of thoughts, feelings, sounds and sensations also feature.

Procedure

Participants completed pre- and post-intervention tasks and self-report measures in the MERLiN labs in the Department of Psychological Sciences at Birkbeck. After signing consent forms, they completed the questionnaires. They were then seated in front of the eye tracker at a viewing distance of 60cm, with their heads in a fixed position using a chin and forehead rest to complete the anti and prosaccade tasks. The lights were dimmed and the eye tracker calibration procedure was run. This required participants to fixate on a series of nine points on the screen. Following successful calibration, participants were instructed not to move their head. Spoken instructions were delivered by the researcher, with a basic summary appearing on screen. Speed and accuracy of response were emphasised, as was the need to keep as still as possible. There were 16 practice trials without on screen feedback, though the researcher used live eye-tracking data to check the participant was performing the task sufficiently, and reiterated the instructions if necessary. The main experimental task was then run.

After this, participants moved to another dimly lit experiment room to complete the CDT task, where instructions were emphasised. A series of 24 practice trials was run with the researcher in the room to ensure that performance was above 50% - if not, the practice was run again. A total of 160 experimental trials was divided into 4 blocks of 40 trials, with a short break after each block. The task lasted approximately 8 minutes.

Following the CDT task, the online WM training and guided MMP was explained to the participants (as appropriate). For the WM training task participants practiced a few trials of the *n*-back task with the experimenter in the lab to get familiar with the task and clarify any questions. They were instructed to complete the task for a continuous number of seven days at approximately the same time every day. Participants could see a summary of their daily performance and progress at the end of the training session. They were told that the experimenter would be tracking their performance and completion rates each day. All data concerning participant performance on the training task (e.g., login, missed trials, time spent on task) was recorded, with the experimenter monitoring performance remotely. Participants who missed training on one day were permitted to continue and complete the training regime one day later. MMP was introduced to the participants in the lab following the first CDT task, as appropriate. Participants were told to access the online mindfulness audio tape via a specific link issued for the participant. Participants logged into a secure online platform which took them through the mindfulness exercise, after which they indicated using the link when they had completed the session and login and logout details as well as time spent on mindfulness were recorded. The combined group (MMP and dual *n*-back) did both tasks at the same time with the sequence counterbalanced across participants, to avoid order effects. Participants began the online training the day after the pre-intervention session. After training participants were then re-tested on the CDT and antisaccade tasks the day after their last training session. Seven days after the second test session, self-report questionnaires were administered a third time, using the online survey platform Survey Monkey.

Data Preparation

Training improvement. The prime measure of improvement was training slope. For this, regression was used to produce a coefficient which represented the rate of each participant's improvement and amount of engagement across training days.

Antisaccade measures. There were two main dependent variables: latency of correct antisaccades, and error rate (percentage of incorrect antisaccades). Percentage of saccadic errors and mean latency of correct saccades were calculated on an individual basis. Latency was defined as the elapsed time between onset of the target and the first saccade in the correct direction. In keeping with Derakshan et al., (2009), saccades occurring less than 83ms after target onset were considered anticipatory and were excluded from analysis (.69% of antisaccade trials). Incorrect saccades were defined as the first saccade after target onset towards the target in the antisaccade condition or away from the target in the prosaccade condition. Trials where no eye movements were made or where the eye-tracker failed to record data ("no saccade" trials) were discarded (1.37% of antisaccade trials).

Working memory capacity. Participants' WMC was estimated from their results on the CDT using a well-established formula for this paradigm (Cowan, 2001; Owens et al., 2013; Vogel et al., 2005). The formula used is K = S(H-F), where K is WMC, S is the array size (4 or 2), H is the hit rate, or proportion of accurate responses when a change has occurred, and F the false alarm rate, or proportion of erroneous responses when a change has occurred.

Results

Training Improvement

Performance on the adaptive dual *n*-back task for the two groups who underwent *n*-back training over the seven-day training period can be seen in Figure 1, which shows the average level of difficulty achieved.

Insert Figure 1 here

Higher levels of difficulty (level of *n*) achieved by the end of the week indicate mean performance on the training task improved from beginning (day 1) ($M = 1.54$, $SD = .47$) to end of training (day 7) ($M = 2.15$, $SD = .96$), $t(14) = 3.19$, $p < .008$, in the *n*-back group. The slope of improvement was significantly different from zero, $t(14) = 3.14$, $p < .008$. The combined *n*-back and MMP group also improved: mean performance level of n rose from 1.66 ($SD = .43$) at day 1 to 2.45 ($SD = .67$) at day 7, $t(14) = 4.98$, $p < .001$. Slope of improvement was also significantly different from zero in this group, $t(14) = 5.29$, $p < .001$.

The control group attained 94.62% accuracy in 1-back training over the testing period, and percentage accuracy scores remained level from the first ($M = 94.27$, $SD = 3.87$) to last ($M = 94.65$, $SD = 4.94$) day of training.

Change detection task (CDT)

Working memory capacity (K) increased from pre-intervention ($M = 1.27$, $SD = .83$) to post-intervention ($M = 1.53$, $SD = .79$). A mixed ANOVA with Group (control, *n*-back, MMP, and combined) and Time (pre intervention – post intervention) confirmed this through a main effect of Time, $F(1,56) = 8.95$, $p = .004$, $\eta^2_p = .14$. The main effect of Group was not significant, $F<1$, and neither was the interaction of Time X Group, $F(3,56) = 1.27$, $p = .29$, $\eta^2_p = .06$.

Antisaccade task

The groups did not differ on anticipatory saccades at pre- or post-intervention (both *F*s < 1, ns), and the same was found for no saccade trials (both *F*s < 1).

Saccadic latencies. Saccadic latencies were subjected to a 2 (Time: pre-intervention, post-intervention) X 2 (Task: antisaccade, prosaccade) X 4 (Group: control, MMP, *n*-back and combined) mixed ANOVA. Latencies got faster at post- (M = 230.1, SD = 25.47) vs. pre-intervention (M = 235.91, SD = 30.5), as demonstrated by a main effect of Time, $F(1, 56) = 4.98$, $p = .03$, $\eta^2_p = .08$. A Time X Task interaction was observed, $F(1, 56) = 4.62$, $p = .03$, $\eta^2_p = .08$, which showed that while antisaccade latencies got faster from pre- (M = 268.54, SD = 39.82) to post-intervention (M = 258.86, SD = 32.57), prosaccade latencies did not, (pre-intervention, M = 203.30, SD = 30.65; post-intervention M = 201.30, SD = 29.57). The main effect of Group, the interaction of Time X Group and the three-way interaction of Time X Group X task were not significant: all Fs < 1, *ns*.

However, consistent with our predictions, we found that slope of improvement (degree of engagement with training) correlated with improvements on antisaccade latencies (pre- to post-intervention), in those who undertook *n*-back training (combined and *n*-back groups): $r = -.36$, $N = 30$, $p = .05$ (see Figure 2), such that greater levels of improvement were met with better performance in antisaccade latencies.

Insert Figure 2 here

Saccadic error rates. Saccadic error rates were subjected to a 2 (Time: pre-intervention, post-intervention) X 2 (Task: antisaccade, prosaccade) X 4 (Group: control, MMP, *n*-back and combined) mixed ANOVA. Error rates reduced post-intervention (M = 6.14, SD = 5.85) relative to pre-intervention (M = 8.78, SD = 8.43), as revealed by a main effect of Time, $F(1,56) = 8.56$, $p = .005$, $\eta^2_p = .13$. A main effect of Task was also observed, $F(1, 56) = 40.39$, $p < .001$, $\eta^2_p = .41$, that demonstrated antisaccade errors (M = 11.02, SD = 9.56) were greater than prosaccade errors (M = 3.91, SD = 5.17). No other main effects or interactions reached significance, all Fs < 1, ns.

Self-reported symptomatology

Trait worry. Worry scores significantly reduced from pre-intervention (*M* = 57.58, *SD* = 8.60) to post-intervention (*M* = 51.70, *SD* = 10.84), with sustained reductions at one week follow-up (*M* = 51.17, *SD* = 11.46). A mixed ANOVA with Group and Time (3 levels) confirmed a main effect of Time, $F(2,112) = 25.95$, $p < .001$, and a significant Group X Time interaction, $F(5,112) = 3.47$, $p < .007$. Figure 3 shows that, while reductions in worry were observed from pre- to post-intervention in the *n*-back and MMP groups (corrected *p*s < .01), the combined group showed the biggest decrease from pre-intervention to follow-up, $t(14) = 4.17$, $p = .001$. This group demonstrated significant reductions from post-intervention to follow-up as well, $t(14) = 5.35$, $p < .001$, suggesting the combination of *n*-back training and MMP yielded longer-term positive effects.

Insert Figure 3 here

Additional analysis

Training improvement and change in self-reported symptomatology. In line with previous findings on the effects of training improvement on anxiety-linked symptomatology (Sari et al., 2016), and recent recommendations to examine training-related gains as a function of training engagement/improvement on training tasks (von Bastian & Oberauer, 2014), we examined how worry scores changed as a function of training engagement in the n-back group. Change in worry from post-intervention to one week follow-up was marginally correlated with training engagement on the *n*-back task, as measured by the slope of improvement: $r = -.48$, $p = .07$, with 22.9% shared variability, showing greater improvements met with lower scores at follow-up (see Figure 4a). Given the small sample size, this result is suggestive of a meaningful relationship with a substantial effect.

Correlational analysis of difference scores for all other self-report measures (state anxiety, positive affect, negative affect, rumination and resilience, see supplementary material for descriptive statistics) and training improvement in the dual *n*-back group demonstrated only one other significant relationship. This was between changes in resilience from pre- to post-intervention and training slope:

r = .53, *p* = .04, indicating that the greater the level of engagement/improvement, the greater the resilience scores (see Figure 4b). Additionally, improvements in resilience scores at post-intervention were significantly correlated with reductions in worry at follow-up, relative to post-intervention, *r* = .64, *N* = 15, *p* = .01, suggesting a possible link between resilience and worry (see Figure 4c). This pattern was also confirmed in the combined training group, who practiced the dual *n*-back and MMP: *r* = .58, *N* = 30, *p* < .002 (see Figure 4c). No other correlations reached significance.

Insert Figure 4 here

Discussion

The present study aimed to investigate the combined and individual effects of WM training and MMP on attentional control/WMC in a sample of high worriers, and to examine whether these effects transferred to measures of worry and other self-reported symptomatology. The role of attentional control and WMC in excessive anxiety and worry has been highlighted in recent theoretical models (see Berggren & Derakshan, 2013). However, despite burgeoning interest in WM training and widespread use of mindfulness-based therapies in clinical practice, individual and combined effects have yet to be investigated in a single study. Considering the debate surrounding the efficacy of WM training (e.g. Shipstead et al., 2012), and the lack of clarity regarding the cognitive underpinnings of MMP (e.g. Chiesa et al., 2011), investigation of transfer of training-related gains onto other cognitive measures is highly apposite. Transfer to self-reported symptomatology measures would also have important clinical implications.

Our initial and principal analytic approach concerning transfer-related gains to antisaccade and CDT performance did not find that improved working memory performance was modulated by group. All participants demonstrated enhanced cognitive control, as measured by the antisaccade and

CDT task. This was somewhat unexpected, given the outcomes of similar studies (Owens et al. 2013, Sari et al. 2016), and hence contrary to our hypotheses. However, as previously noted, results of cognitive training studies have varied, with some failing to observe transfer-related gains to unrelated tasks (Onraedt & Koster, 2014). Our study, in this respect, continues the ongoing debate regarding working memory training (see Melby-Lervag & Hulme, 2013, for a meta-analytic review), showing an absence of effect. Furthermore, as this lack of between-group difference in WMC is observed alongside a significant reduction in self-reported worry between groups, it also appears to be at odds with attentional control theory.

Our secondary, within-group, findings, however, add important nuance to these points and merit discussion. These findings suggest the relationship between WM training and WMC may be more complex than first posited in the literature. By considering outcome measures as a function of training improvement in our two adaptive *n*-back groups, we observed three correlations of note. Firstly, it appears that there is a meaningful relationship between level of WM training-related improvement and improved attentional control, as assessed by the antisaccade task in individuals who undertook adaptive dual *n*-back training on its own and in combination with MMP. Secondly, individuals who completed the combined MMP and *n*-back training showed the greatest reductions in self-reported worry pre-intervention to one week follow-up post-intervention. Thirdly, there was a trend towards an association between WM training-related improvement and longer-term reduction in levels of self-reported worry, a relationship that could be influenced by increased resilience as a function of training.

It is prudent to note that without the within-group analysis, our results could have been construed as disappointing, as they found no between-group effect on either of our cognitive measures. Because our original design primarily focused on between-group analysis, our correlational results are limited by lack of randomisation, and we acknowledge the potential for known and unknown confounds. However, this study is not the first to consider within-group analysis in this context (e.g. Sari et al., 2016; Bastian & Oberauer, 2014). What has emerged from our findings is that between-group analysis may be unable to take into account considerable heterogeneity in individual engagement with our working memory training task. We find a tentative link between WM training improvement, cognitive improvement, and reduction in worry that is worthy of further investigation, and suggest these results proffer provisional support for the notion there are individual differences in attentional control plasticity, and that these differences extend to training transfer effects. Individual differences in rates of improvement have been posited as a contributing factor in discrepancies in WM training experiments by Moreau (2014), who encourages caution when interpreting seemingly incompatible findings.

With the above caveats in mind, we consider the implications of our three findings below.

Training-related gains on attentional control

WM training-related gains on attentional control were investigated via an antisaccade task. Post-intervention, all groups improved on both antisaccade latency and error rate measures across time, initially indicating no specific training effects. However, examination of the *n*-back and combined groups' training performance showed a relationship between training improvement and changes in antisaccade latencies. Higher engagement with training was associated with improved antisaccade performance. This is indicative of a meaningful relationship, and although preliminary, it is an important finding. Mrazek, Franklin, Phillips, Baird and Schooler (2013) assert the best evidence for improved cognitive ability stems from studies featuring a training task dissimilar to the outcome measure. The *n*-back task is designed to improve fundamental processes related to WM, targeting a general pool of resources which is not modality specific. We have demonstrated transfer to a specific task which is considered a process pure measure of inhibition (Friedman & Miyake, 2004), and which cannot be accounted for by similarity in training and testing contexts. This finding contrasts with a recent study of high trait anxiety individuals which did not observe training-related gains to performance on the antisaccade task (Sari et al., 2016). The authors posit the use of emotional targets in their version of the antisaccade task, as opposed to neutral stimuli, may have activated specific processes related to selective attention and the inhibition of threat-related stimuli. Here, our use of neutral stimuli avoided the complicating factor of threat-response to valenced material and enabled us to demonstrate a clear effect towards transfer-related gains after just seven days of training.

Effects of mindfulness meditation practice

The MMP group significantly reduced worry scores pre-intervention to follow-up, replicating previous findings (Delgado et al., 2010; Lenze et al., 2014) and suggesting MMP can be an effective method of reducing worry. There was no transfer to either of the cognitive measures, which is consistent with previous studies of similar length, which found no significant improvements in top-down attentional processes post-intervention (Anderson et al., 2007; Polak, 1999; Tang, 2007). Our findings, together with these studies, suggest short-term MMP may improve aspects of wellbeing, but is not sufficient to impact cognitive functioning in the way long-term MMP seems to (e.g. Hodgins & Adair, 2010).

The results of the combined training group, however, which undertook both *n*-back and MMP, present an exciting prospect for clinical practitioners working with anxiety disorders. This group demonstrated significant improvement in working memory over the course of the week, and the impressive mean levels of *n*-back achieved indicated high levels of engagement with the WM training. Combined training was associated with a significant reduction in worry from post-intervention to follow up one week later, suggesting individuals participating in MMP may benefit from longer-lasting reduction in negative symptomatology if they engage in concurrent cognitive training with the *n*-back task. One explanation for this is that MMP utilises, and its effects depend upon, pre-frontal mechanisms. This is consistent with Bishop et al.'s (2004) conceptualisation of mindfulness, which links it to attentional control and the inhibition of unnecessary elaborative processing. It appears successful MMP requires attentional control, which *n*-back training is known to boost, and that increasing attentional control increases the positive effects of MMP. According to Teasdale, Segal and Williams (1995), these effects include teaching individuals to identify destructive thought patterns sooner, and to process this information in a neutral way that facilitates cognitive flexibility, enabling the individual to reduce worry and self-criticism. In this way, *n*-back training potentially facilitates MMP, increasing its effectiveness and positive impact on emotional vulnerability.

Training-related gains on self-report measures

Participants in all conditions experienced decreases in worry pre- to post-intervention. This finding is consistent with other studies that have noted anxiety reduces over time (Ramsawh, Raffa, Edelen, Rende, & Keller, 2009; Wanmaker et al., 2015). However, individuals in the *n*-back group showed a trend toward correlation between training slope improvements on the *n*-back task and better follow up worry scores relative to post-intervention, as well as a significant correlation between training slope and resilience difference scores. Participants in the *n*-back group who engaged more with training reported higher levels of resilience post-intervention than pre-intervention, suggesting *n*-back training has broader beneficial effects than on worry alone.

Together, these findings are a compelling argument for the importance of considering engagement levels when reporting effects of cognitive training. They also corroborate the results of Sari et al. (2016), who found a significant effect of task engagement (indexed by level of training improvement) on change in trait anxiety. In their study, participants who engaged more with 15 days of training showed a significantly greater decrease on trait anxiety scores than those who engaged less. Siegle et al. (2014) emphasises the importance of engagement in training for clinical benefits, pointing out that targeting a specific process via a cognitive task is likely to be dependent on ability to engage with the task. Our results support this notion: it appears engagement with *n*-back training is crucial if people are to see both cognitive transfer and improvement on measures of wellbeing. This is an important consideration from a clinical perspective: people who don't improve on the task may be discouraged, which may maintain or even exacerbate negative symptomatology. Confirmation that comprehension of the task is sufficient, provision of ongoing support during training, and assessment of motivation prior to training may help to ensure individuals experience the full benefits of *n*-back training.

In the *n*-back training group, improvement in worry scores over the second week of the study also significantly correlated with improvement in resilience scores over the first week. The timeline of observed correlations prompts us to speculate that resilience, a measure of stress-coping ability (Connor & Davidson, 2003), may be an important mechanism by which the relationship between training gains and reductions in worry can be explained. Therefore, training related gains are associated with greater changes in resilience and a greater reduction in worry over time. There is evidence to support this assertion - hope, a factor of resilience (Lloyd & Hastings, 2009), has been shown to function as a protective factor against psychological distress, and higher hope has been associated with lower worry (Ogston, Mackintosh, & Myers, 2011). Our results corroborate this, and present the possibility that training which increases one's ability to cope with stress may decrease levels of worry.

Directions for future research and limitations

In line with Bishop et al.'s (2004) theory of mindfulness, our results suggest MMP utilises pre-frontal mechanisms, including attentional control. We observed reductions in worry were greater and longer-lasting when participants engaged in WM training alongside MMP, indicating mindfulness may involve processing efficiency. WM training's potential to improve processing efficiency therefore makes it an excellent candidate for further investigation as an experimental tool that may enhance the clinical outcomes of not only MMP, but other clinical treatments which stand to benefit from greater attentional control. These include cognitive behavioural therapy (CBT), the success of which has been predicted by pre-frontal regions implicated in attentional control. Klumpp, Fitzgerald, Angstadt, Post and Phan (2014) reported patients with an anxiety disorder who exhibited greater attentional control pre-treatment were more likely to benefit from CBT. Siegle, Ghinassi and Thase (2007) have highlighted the advantages of adjunctive interventions which target prefrontal control, rather than specific symptoms, noting they could "improve the efficacy of conventional therapies…by allowing patients to overcome specific roadblocks to their success in these therapies" (p. 238). As decreased prefrontal control has been observed in a host of conditions, ranging from depression (Mayberg et al., 1999) to obsessive compulsive disorder (van den Heuvel et al., 2005) and addiction

(Goldstein et al., 2004), the current study presents exciting avenues for future research to investigate WM training as an adjunct to an abundance of clinical treatments.

Our results indicate *n*-back training has the potential to impact attentional control and aspects of wellbeing when participants engage with the training, inviting further research as to what level of task improvement is sufficient to facilitate transfer to cognitive and emotional vulnerability measures. Researchers could also look to increase motivation to engage by introducing game elements and frequent, immediate feedback about performance (e.g. reward points), which have been shown to positively impact motivation (Prins, Dovis, Ponsioen, ten Brink & van der Oord, 2011).

There are several ways in which the current study could be improved. It will be fruitful for future studies to conduct training interventions with follow-up periods beyond one week, to investigate the stability of transfer effects. Additionally, studies would benefit from a larger sample size. With 15 participants per group in the current study, individual differences may have impacted results at group level. This may account for the lack of group differences between the control and experimental groups post-intervention – a weakness of our findings when considered from a traditional analytic approach. However, as research begins to show the importance of analysing results as a function of training improvement/engagement (e.g. Sari et al., 2016), we predict training studies will shift increasingly towards within-group analysis. With this in mind, future research could attempt to index mindfulness, so that MMP training-related gains may be examined. Self-report measures of MMP are a topic of contention in the literature (see Grossman, 2011), and a recent systematic review found important limitations in the field remain (Park, Reilly-Spong, & Gross, 2013). However, efforts to refine measures are ongoing, and are worth considering in future studies (Brown, Ryan, Loverich, Biegel, & West, 2011). Finally, given the small sample size and the fact we did not exclude any data, we consider the observed trends towards correlations between training improvement and attentional control/vulnerability outcomes to be worthy of discussion. Replication is necessary to further elucidate the relationship between training improvement, cognitive and wellbeing measures.

It is clear that longer training times are associated with larger training gains for both *n*-back training (Jaeggi et al., 2008) and MMP (e.g. Hodgins & Adair, 2010). Owens et al. (2013) used a similar amount of *n*-back training days to the current study, but utilised breaks over weekends to spread training over 2 weeks. This may account for our failure to replicate findings that *n*-back training improved performance on a measure of WMC (Owens et al, 2013). Longer training times coupled with breaks in training may produce the best results for clinical intervention. Training-related gains did not transfer to our measure of WMC in the same way as they transferred to the antisaccade task. This was unexpected, as performance on the CDT has been shown to correlate with the ability to filter irrelevant information (Vogel et al., 2005), and hence is thought to be indicative of executive control abilities. It is possible the CDT and antisaccade task tap different facets of attentional control (Banich, 2009; Friedman et al., 2008). Another possibility is the CDT did not feature large enough set sizes for differences to be discerned. Shin, Lee, Yoo and Chong (2015) examined the effects of inhibition training on WMC measured via a change detection task and found the training group's WMC increase was significantly higher for the larger change detection set sizes of 4, 5, 6 and 7. They conclude "filtering training was particularly effective for larger memory loads (i.e., more difficult conditions)." (p. 11). Pailian and Halberda's (2014) study of the CDT as an estimate for visual WMC also found much larger variance in K scores where arrays had a set size of eight rectangles, as compared to a set size of four. They posit, "The variability in performance at set size 8…may reflect individual differences in the ability to effectively organise large amounts of information at encoding" (p. 397). Their findings suggest a version of this task with a condition featuring a set size of 8, with greater numbers of distracting stimuli, may provide a more sensitive measure of executive control abilities. This is consistent with Kane and Engle's (2003) observation that without distraction or interference, there tend not to be individual differences in task performance as a function of WMC.

Conclusions

In sum, the conclusions of this study are important in two ways. Firstly, our findings indicate practitioners of mindfulness meditation stand to benefit from simultaneous WM training. They support the theoretical assumption that MMP utilises the same pre-frontal mechanisms that the *n*-back task has been shown to tap, including attentional control, and suggest that the *n*-back task's positive impact on these mechanisms facilitates the effects of MMP, resulting in greater positive effects on wellbeing. In the same way, WM training may serve as a catalyst for other clinical treatment, including cognitive behavioural therapy. Secondly, we have demonstrated engagement in the *n*-back task is crucial if individuals are to see transfer to both cognitive performance and measures of symptomatology. Our evidence, together with recent research (Siegle et al., 2014; Sari et al., 2016), provides compelling support for the notion that training studies must identify improvement/engagement levels and take these into consideration when drawing conclusions about the efficacy of a training intervention. From a clinical perspective, and with due caution given the limited sample size, we suggest participants who are able to engage with WM training stand to benefit from boosted effects of MMP and improved clinical outcomes, with exciting implications for other forms of clinical treatment.

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Footnote

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.

Figure Captions

Figure 1. Mean *n*-back level achieved by *n*-back and combined groups across the training period.

Figure 2. Relationship between *n*-back training (slope of improvement) and change in antisaccade latency (negative values indicate improvement at post- vs pre-intervention).

Figure 3. Mean self-reported worry scores at pre-intervention, post-intervention, and one week follow-up.

Figure 4. a) correlation between change in worry and slope of training improvement in the *n*-back group, b) correlation between change in resilience and slope of training improvement in the *n*-back group, c) correlation between change in resilience and change in worry in the *n*-back and combined groups.

Figure 1

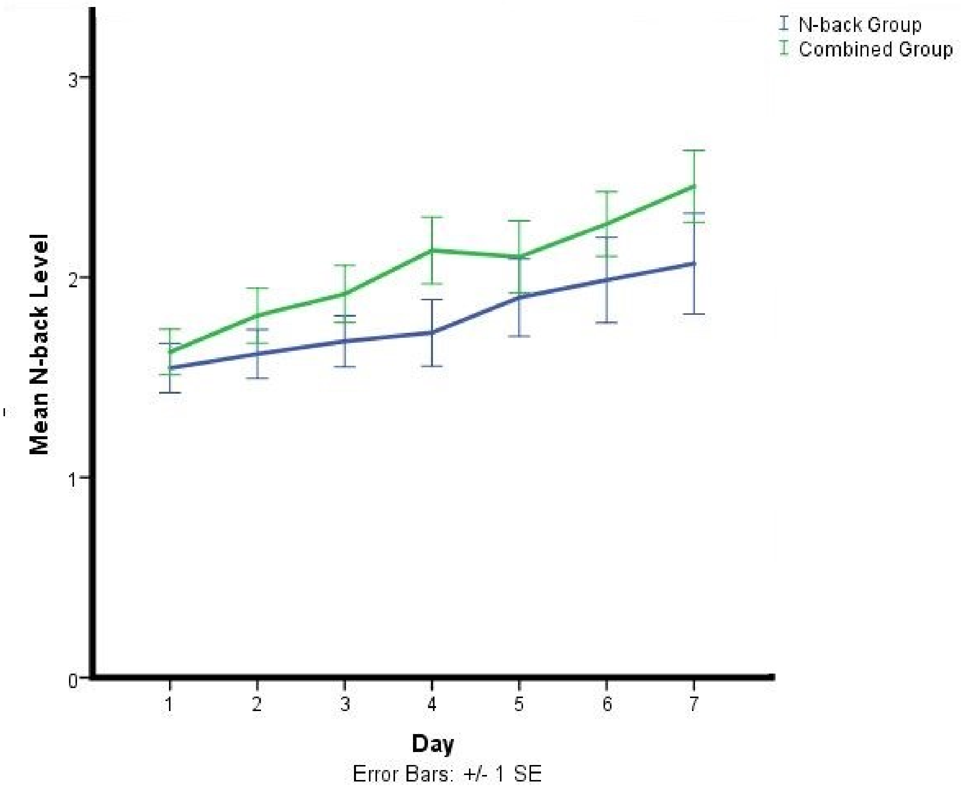
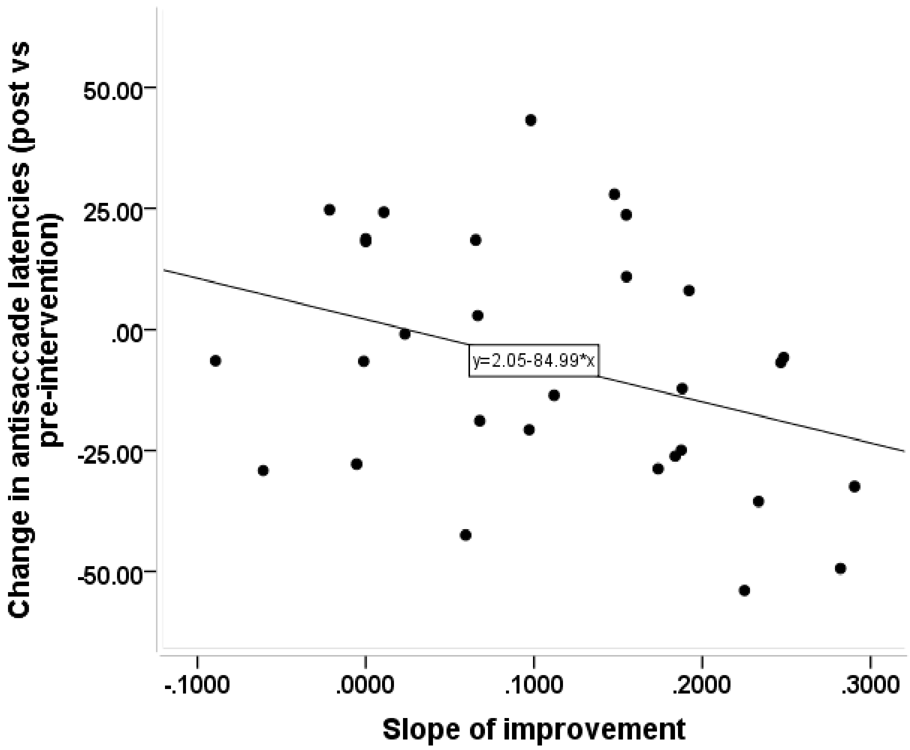

N-back Group
Combined Group
Mean N-back Level
3
2
1
0
1
2
3
4
5
6
7
Day
Error Bars: +/- 1 SE

Figure 2



Change in antisaccade latencies (post vs pre-intervention)
50.00
25.00
.00
-25.00
-50.00
y=2.05-84.99*x
-.1000
.0000
.1000
.2000
.3000
Slope of improvement

Figure 3

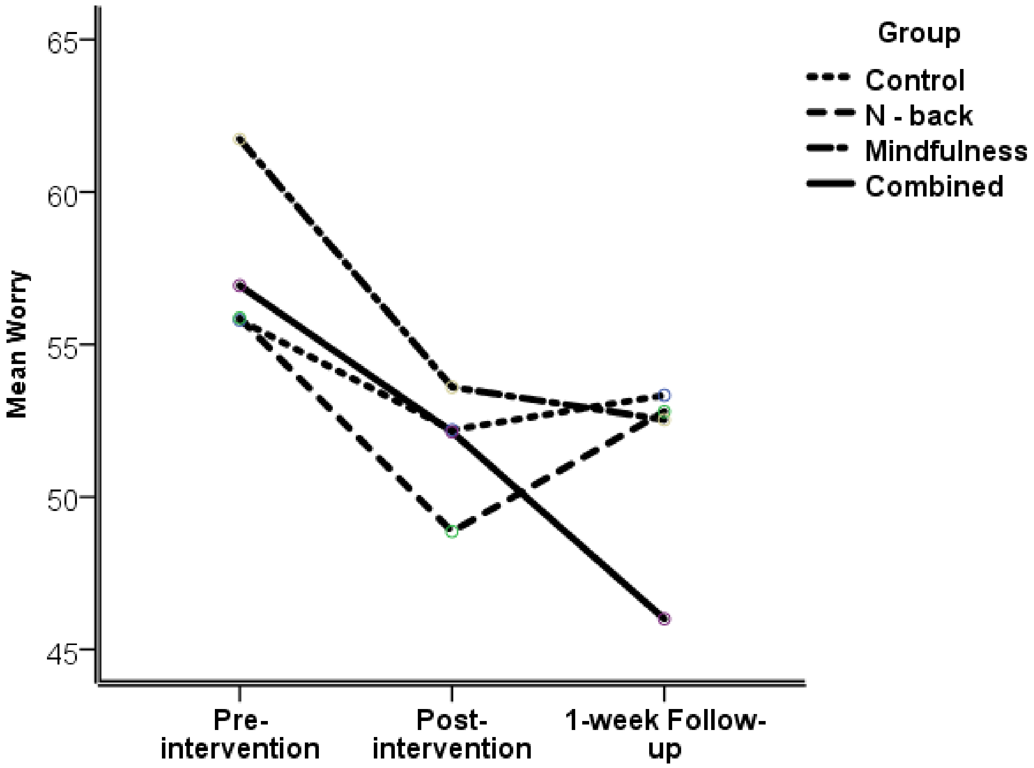
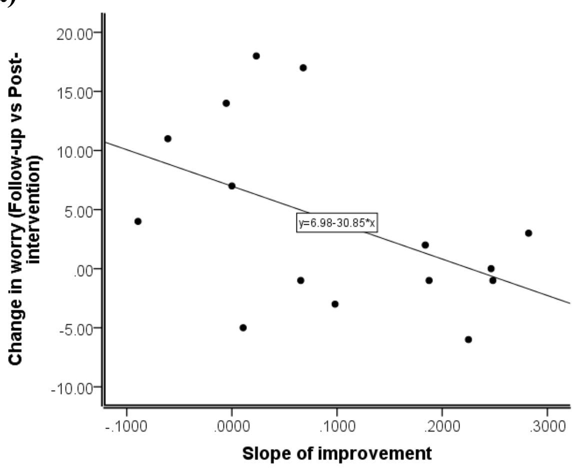

Group
Control
N - back
Mindfulness
Combined
Mean Worry
65
60
55
50
45
Pre-intervention
Post-intervention
1-week Follow-up

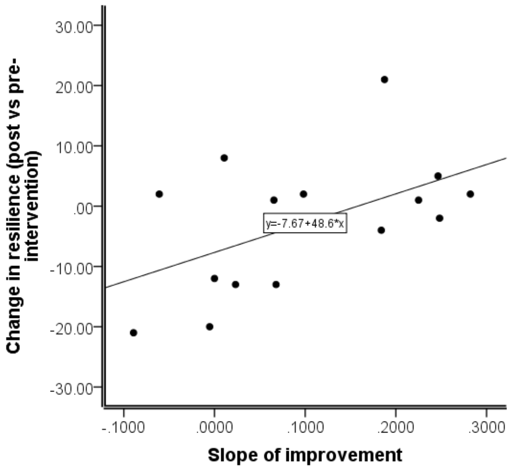
Figure 4

a)



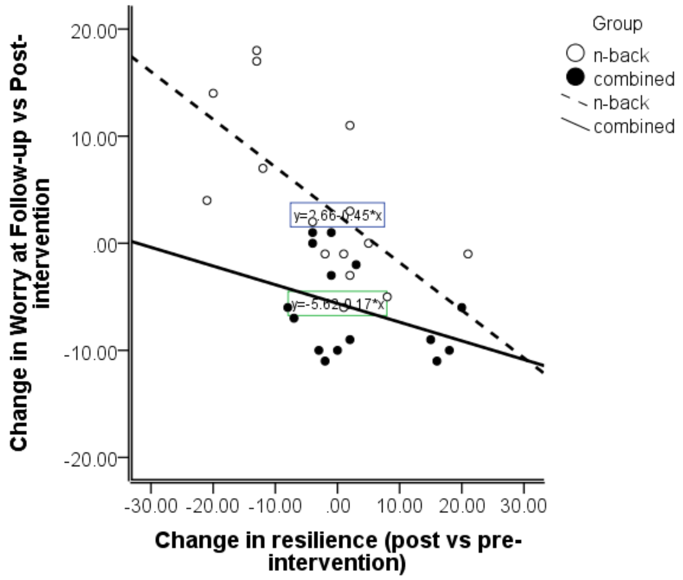
20.00
15.00
10.00
5.00
.00
-5.00
-10.00
Change in worry (Follow-up vs Post-intervention)
y=6.98-30.85*x
-.1000
.0000
.1000
.2000
.3000
Slope of improvement

b)



30.00
20.00
10.00
.00
-10.00
-20.00
-30.00
Change in resilience (post vs pre-intervention)
y=-7.67+48.6*x
-.1000
.0000
.1000
.2000
.3000
Slope of improvement

c)



Supplementary Material

Table 1: Means and Standard Deviations for Self-Report Measures at Times Pre-intervention (Time 1), Post-intervention (Time 2) and 1-Week Follow-up (Time 3)

Measure	Time	Group			
		Control	N-back	Mindfulness	Combined
Worry (PSWQ)	1	55.80 (11.30)	55.87 (8.53)	61.73 (7.15)	56.93 (5.89)
	2	52.20 (12.54)	48.87 (9.05)	53.60 (10.56)	52.13 (11.48)
	3	53.33 (12.82)	52.80 (9.29)	52.53 (10.02)	46.00 (12.80)
Anxiety (STAI-S)	1	35.73 (10.24)	36.07 (7.12)	40.67 (10.02)	33.00 (8.56)
	2	37.47 (10.09)	41.27 (11.71)	35.00 (8.30)	31.13 (8.36)
	3	38.33 (12.78)	43.00 (13.86)	36.67 (12.84)	37.93 (11.50)

Positive Affect (PANAS)	1	29.80 (6.74)	29.27 (9.23)	29.67 (8.82)	33.93 (7.05)
	2	29.53 (8.36)	29.27 (8.46)	34.07 (7.13)	33.93 (9.33)
	3	29.60 (9.13)	33.73 (8.57)	36.13 (5.72)	34.20 (6.90)
Negative Affect (PANAS)	1	18.93 (8.46)	17.40 (5.68)	18.47 (7.31)	16.20 (5.88)
	2	15.60 (4.64)	18.00 (7.58)	16.40 (5.73)	15.20 (6.07)
	3	18.93 (6.87)	22.87 (8.30)	18.40 (5.93)	17.93 (4.98)
Rumination (RRS)	1	56.47 (11.28)	45.87 (10.27)	50.33 (10.59)	53.67 (8.50)
	2	55.67 (11.59)	47.80 (9.60)	46.47 (9.86)	51.73 (9.03)
	3	57.47 (14.26)	47.60 (17.80)	49.27 (11.70)	52.20 (9.77)
Resilience (CDRS)	1	58.20 (13.01)	65.80 (12.77)	63.20 (9.57)	68.67 (12.16)
	2	59.73 (13.51)	62.93 (12.85)	65.47 (10.43)	71.60 (9.25)
	3	57.00 (13.26)	58.60 (22.36)	65.47 (10.87)	69.67 (12.91)

Standard deviations are shown in parentheses.