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Mindfulness and Anxiety: The role of attentional control and threat-processing

by

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ABSTRACT

FACULTY OF SOCIAL AND HUMAN SCIENCES
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Mindfulness and Anxiety: The role of attentional control and threat-processing

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Current models of anxiety propose that deficits in cognitive and attentional control are risk factors for the development and persistence of worry and anxiety (Eysenck, Derakshan, Santos, & Calvo, 2007). Clinically anxious individuals demonstrate maladaptive attentional biases towards anxiogenic threatening stimuli that may be modulated by biases in attentional subsystems (Derryberry & Reed, 2002). Mindfulness-based treatments have shown some efficacy in treating anxiety and mood disorders (Evans et al., 2008). Mindfulness treatments endorse deliberate, non-judgemental attention and have demonstrated a range of effects on several behavioural measures of attention (Josefsson & Broberg, 2011; Moore & Malinowski, 2009). This thesis sought to clarify the effects of mindfulness on attentional functioning, and the extent to which this association could reduce/protect against anxiety by correcting dysfunctional attentional biases to threat.

A cross-sectional study identified attentional control and worrying rumination as key elements in the relationship between dispositional mindfulness and anxiety. The first in a systematic series of experiments looked at the effects of two different aspects of mindfulness (focused attention and open-monitoring meditation) on a measure of attentional subsystem functioning (attention network test). The next study examined the effects of a more extensive mindfulness intervention on two measures of threat-appraisal (eye-blink startle), and attention-to-threat (antisaccade task). Finally, a novel experimental model of anxiety (7.5% CO_2) was used to examine acute effects of focused attention and open-monitoring meditation on autonomic and self-report measures of anxiety.

Findings from this thesis were in line with evidence that mindfulness increases executive attention (Jha, Krompinger, & Baime, 2007; Tang et al., 2007) and showed some evidence that dispositional mindfulness may be related to maladaptive threat-processing. Our novel finding that mindfulness protected against experimentally-induced anxiety support our evidence that improvements in attentional performance may be behind the efficacy of mindfulness-based treatments for anxiety and GAD.

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Declaration of Authorship

I, *Ben Ainsworth,* declare that the thesis entitled **Mindfulness and Anxiety: The role of attentional control and threat-processing** and the work presented in it are my own and has been generated by me as the result of my own original research. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University;
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- Where I have consulted the published work of others, this is always clearly attributed;
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all main sources of help;
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
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Chapter 1

Mindfulness, attention and threat-processing: implications for anxiety

'Mindfulness' is a fast-growing approach, based on Buddhist meditation principles, that is becoming increasingly common as a cognitive and behavioural therapy for anxiety. To determine the mechanisms of mindfulness and their potential for anxiety treatment this review examines the role that attention and threat-processing play in the aetiology and maintenance of anxiety, and considers cognitive mechanisms through which mindfulness may effect positive change.

Anxiety and its prevalence in society

Fear and anxiety are considered part of the defence system, inhibiting our interaction with harmful influences and physically equipping us to better face threats that cannot be avoided. Fear triggers alterations in the sympathetic nervous system in order to equip the body for a 'fight-or-flight' response. The fight-or-flight response enables quick reactions to threat – either by delivering a situationally-appropriate response (fight) or by escaping the threat entirely (flight). Anxiety is as an adaptive component of fear – helping us plan for and thus avoid such potential threats (LeDoux, 2000). It follows that clinical levels of anxiety can be conceptualised as defence mechanisms which have been activated incongruously (Behar, DiMarco, Hekler, Mohlman, & Staples, 2009).

Anxiety symptoms vary across individuals, but encompass both physical (such as breathlessness, feelings of nausea and increased perspiration) and psychological characteristics (such as difficulty concentrating, agitation and irritability). Clinical levels of anxiety are diagnosed when the magnitude of these symptoms causes significant distress and interferes with day-to-day life over a significant period of time. Anxiety disorders have an estimated 12-month prevalence of 14%, life-time prevalence of 17-21% and are associated with significant personal distress, reduced quality of life and a substantial economic burden (Wittchen et al., 2011) – in the United States, annual estimated medical expenditures, lost productivity and functional impairment are between $42.3 billion and $46.6 billion (Ramsawh, Weisberg, Dyck, Stout, & Keller, 2011). In the EU a conservative estimate of the total annual economic cost in 2010 was €74.4 billion (Olesen, Gustavsson, Svensson, Wittchen, & Jönsson, 2012).

Generalised Anxiety Disorder (GAD) is the most frequent anxiety disorder in primary care, present in 22% of patients who complain of anxiety problems. GAD is characterised by excessive tension and worrying and feelings of apprehension about everyday events over a prolonged period, coupled with a variety of autonomic symptoms. Sufferers typically do not recover without treatment and recovery is hindered by the high comorbidity of GAD and depression. 66% of GAD sufferers have a current additional psychological disorder and 90% have had another disorder at some point in their lives (Wittchen, 2002). Consequently, GAD alone places a significant burden on the individual and society, requiring appropriate research and improvement in psychological treatment.

Psychotropic medications and cognitive behaviour therapy (CBT) both appear effective for treating GAD. There are a number of contemporary models of GAD (see Behar et al., for a review) that all emphasise avoidance of internal affective experiences (through 'worrying'). GAD is characterised by excessive, uncontrollable worry that causes functional impairment, particularly by distracting sufferers from cognitive functioning (Wells, 2005). Worry is defined as internal concerns about negative evaluation by others, and potential aversive consequences to actions (Tallis & Eysenck, 1994). High levels of worry are often associated with low levels of performance in a variety of cognitive tasks (see Sarason, 1988, for a review). Additionally, the effect of worry is not just the increased cognitive demand in maintaining worrying cognitions; the effect is amplified by further cognitive processing as individuals attempt to minimise any anxious state induced (Eysenck, Derakshan, Santos & Calvo, 2007).

Anxiety and the fear system / Why do we get anxious?

Anxiety has evolved from a defense system that is essential for survival – an adaptive function of fear (LeDoux, 2000). While both are aversive threat-responses, fear is the contextual behavioural reaction to an imminent threat, and anxiety is an apprehension of potential threats (future events that may not occur). Consequently, differences in stimuli eliciting each response (i.e. imminent/present or potential/future) have enabled experimental designs to dissociate fear and anxiety in animal and human populations (Grillon, 2002).

Pavlovian conditioning techniques have been used to create *cued-fear* conditions: animals learn to fear a predetermined threat signal (CS) immediately preceding an aversive stimulus (such as a loud noise, or brief electric shock). Thus, presentation of the threat signal induces a brief, intense fear response that quickly subsides (Öhman & Mineka, 2001). However, a CS-response does not reflect the longer-term characteristics of anxiety. Over time, presentation of unpredictable aversive stimuli leads to a generalized state of apprehension with accompanying debilitating cognitive effects (see Mineka & Kihlstrom, 1978 for a review; Dutke & Stöber, 2001) recognised as anxiety.

Information processing models of anxiety

Early conceptualizations of anxiety hold that maladaptive cognitions are crucial to both the emergence and maintenance of anxiety disorders (Dutke & Stöber, 2001). An early cognitive model of anxiety, proposed by Beck (1985), proposes that 'schema' (mental representations of the self and surrounding environment) play a crucial role in the relationship between cognitions and emotional disorders such as anxiety. Initial maladaptive schema cause negative information-processing biases (such as attending to and interpreting information consistent with them, and ignoring that which is inconsistent). This reinforces the original negative schema, resulting in 'negative automatic thoughts', characterised by biased attention towards threatening stimuli and a tendency to interpret emotionally ambiguous stimuli as negative. Thus, negative information biases lead to the activation of negative mood and emotion, and further activation of negative schema (i.e. self-sustaining dysfunctional cognitions).

Similarly, Network Theory provides a model for the association between cognition and emotion, using the concept of emotion as a collection of 'nodes' (Bower, 1981). Part of a general emotion and memory network, an emotion node exists for each distinct emotional state and then becomes active whenever that state is experienced. Nodes that are activated regularly develop associations with other nodes that are accessed at similar times. This causes the formation of a memory and emotion network in which activation of individual nodes spreads through the network causing the activation of other nodes relating to similar emotional information.

Consequently, any experience of negative emotions (such as those elicited in anxious behaviours) activates nodes associated with negative affect, and the subsequent spread of activation across related nodes introduces a bias in the information processing system. Therefore, individuals who have formed strong associative connections between nodes of negative affect (such as those with maladaptive anxiety-related cognitions) will activate these nodes more frequently, strengthening existing biases. As in Schema Theory, maladaptive cognitive biases are self-maintaining and result in reduced cognitive performance in anxious individuals.

Later cognitive models of anxiety

Later cognitive models of anxiety attempt to more accurately define mechanisms behind dysfunctional information-processing biases in anxious individuals, sharing emphasis on maladaptive threat-processing biases in particular.

Mogg and Bradley (1998) proposed a model that includes a ‘valence evaluation system’, which appraises the potential threat of stimuli based on prior experience, situational context and stimulus nature. Bias towards stimuli is a function of higher cognitive processes, such as the inclusion of contextual significance and memorial learning, as well as low-level automatic processing. The valence evaluation system subsequently relates subjectively-judged stimuli to a ‘goal-engagement system’, which then determines the goal-oriented focus of the individual (should the valence-evaluation system assess stimuli as threatening, the goal-engagement system would reduce attentional focus on goal-relevant stimuli).

‘High anxiety’ (HA) individuals have a more sensitive valence-evaluation system, resulting in a tendency to subjectively evaluate stimuli as threatening. Thus, the goal-engagement system is inclined to engage in maladaptive behaviours (i.e. interrupt the processing of goal-relevant stimuli and prioritise processing of perceived threat). Thus, changes in threat-processing behaviours can cause reduced cognitive performance in HA individuals compared to their low anxious (LA) counterparts.

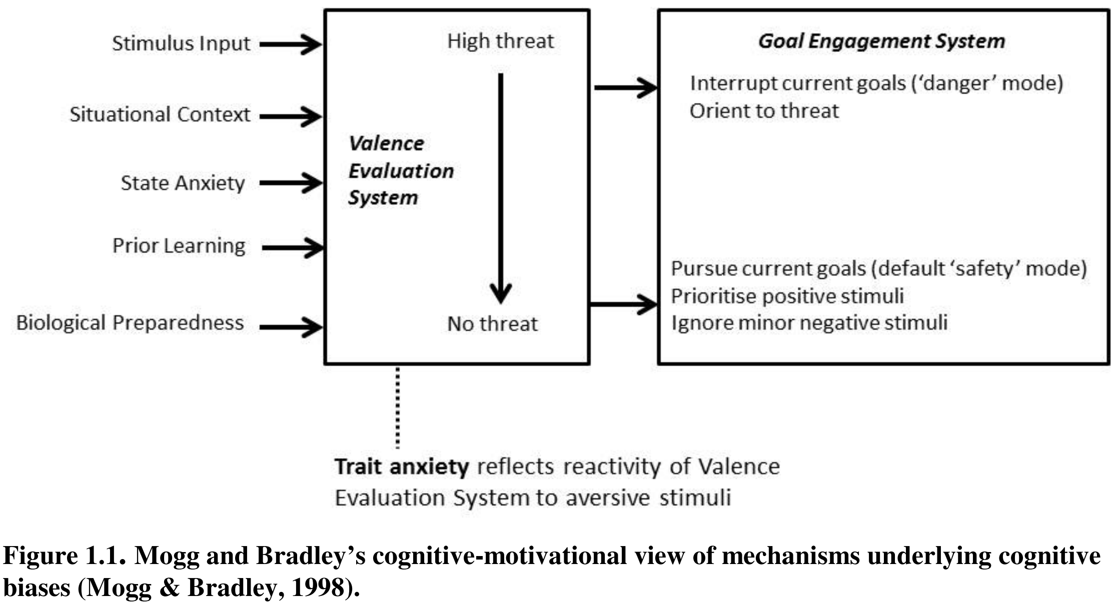

Figure 1.1. Mogg and Bradley’s cognitive-motivational view of mechanisms underlying cognitive biases (Mogg & Bradley, 1998).

Pertinently, the relationship between the valence-evaluation system and the goal-engagement system may not be linear. It is unlikely that maladaptive valence-appraisal would result in the negative automatic thoughts presented in initial cognitive models. Dysfunctional cognitive mechanisms in anxious individuals are characterised by increased attention towards threatening stimuli (vs. non-threatening) and a tendency to appraise stimuli as more threatening than non-anxious counterparts.

Mathews and Mackintosh's (1998) model (Figure 1.2) differentiates between ‘top-down’ attentional processes (goal-related factors, intending to achieve an individual’s current aim) and ‘bottom-up’ processes (situational factors in the environment, such as threatening stimuli). In healthy, non-anxious individuals, attention is optimally managed between top-down and bottom-up, such that goals are achieved while still monitoring for potential threats in the environment. In HA individuals, the balance between bottom-up and top-down is poorly managed, with an attentional bias towards threatening or aversive stimuli.

Notably, there is a general limit to the capacity to perform mental work (i.e. Kahneman, 1973). If attentional resources are sufficient to complete a task (top-down) and still monitor the environment (bottom-up), then threat-processing can be seen as adaptive. However, if joint task demands exceed the available resources, the two processes must be mutually interfering (see Szymura, in Gruszka, Matthews, & Szymura, 2009). Thus, cognitive function is impaired, as any increase in threat-monitoring bottom-up cognitive processes decreases top-down goal-related cognitive processes (Mathews & Mackintosh, 1998).

The model proposes that the top-down/bottom-up attentional balance is a combination of ‘effortful task demand’ (the perceived importance of the task, and therefore the extent of the voluntary attention devoted towards it) and a ‘threat evaluation system’, which assesses the potential threat of environmental stimuli (and therefore the level of attention devoted to threat-monitoring). Anxiety is characterised by an increased influence of the threat-evaluation system, resulting in less attention towards task-relevant, top-down stimuli. Mathews and Mackintosh emphasise an attentional bias in the early, alerting and orienting stage of attention (when a stimulus is initially noticed, but before later stages of processing, such as threat-appraisal).

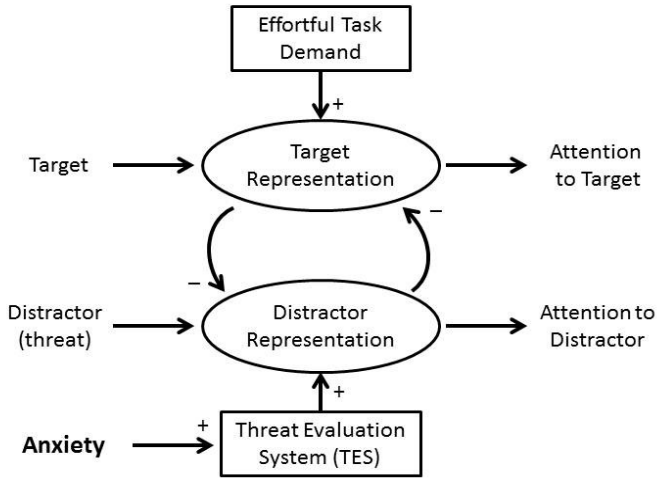

Figure 1.2. Mathews and Mackintosh's model of cognitive biases and the management of them by the Threat Evaluation System (Mathews & Mackintosh, 1998).

'Inefficient attention' models of anxiety

Rather than focusing on threat-related biases as the reason for reduced cognitive performances in anxiety, recent cognitive models have emphasised the functions responsible for these biases – namely, the dysfunctional allocation of limited attentional resources (Processing Efficiency Theory; Eysenck & Calvo, 1992). Based upon the four-component working model of memory (WM; Baddeley, 2001), Processing Efficiency Theory assumes that the main effects of anxiety and worry are on the central executive WM function - as individuals attempt to adequately allocate resources on top-down vs. bottom-up stimuli. The central executive regulates different sensory inputs (namely, the phonological loop, visuo-spatial sketchpad and episodic buffer). Accordingly, cognitive deficiencies should be greater when tasks place specific demands on the central executive – primarily the processing and manipulation of these sensory inputs (Eysenck et al., 2007).

However, there are several limitations of processing efficiency theory. Three of these concern experimental situations: i) reduced executive functioning in the presence of distracter stimuli, ii) reduced executive functioning in the presence of threat-related stimuli (vs. non-threat related), and iii) occasions where anxious individuals cognitively outperform non-anxious counterparts.

Firstly, there is accumulating evidence that anxious individuals' cognitive performance is more impaired by distracting stimuli than non-anxious counterparts (see Eysenck, 1992, for a review of this evidence). However, processing efficiency theory does not provide any satisfactory theoretical hypothesis why this might be the case. Secondly, evidence for processing efficiency theory focuses on cognitive performances during presentation of neutral/non-emotional stimuli. However, there is evidence that HA individuals are more impaired by threatening than non-threatening stimuli (vs. LA counterparts; e.g. Mogg et al., 2000). Again, processing efficiency theory provides no theoretical basis upon which to predict this finding. Finally, in several paired-associate learning tasks (repeated presentation of stimulus pairs until the presentation of one leads to responses associated with the other) HA individuals have outperformed LA counterparts (e.g. Bryne & Eysenck, 1995). Again, processing efficiency theory does not consider such evidence and is unable to provide theoretical grounds for such findings (see Eysenck et al., 2007, for a detailed summary of these experiments). While the notion of 'inefficient resource allocation' seems sound, the notion of dysfunctional WM does not adequately explain cognitive dysfunction in anxiety.

Attentional Control Theory

Eysenck et al. (2007) proposed a model (focusing on top-down vs. bottom-up stimulus regulation) that provides a more precise definition as well as addressing the limitations of processing efficiency theory - attentional control theory. Central to attentional control theory is the assumption that anxiety increases the allocation of attention to threat-related stimuli; specifically, anxiety impairs the cognitive ability to adequately allocate attentional resources to goal-related (top-down) stimuli.

Consistent with the existing cognitive models of anxiety, Corbetta & Shulman (2002) postulated two attentional systems: goal-directed, influenced by knowledge and experience; and stimulus-driven, responding to salient and threatening stimuli, thereby resembling the top-down/bottom-up stimulus attentional systems proposed by Mathews and Mackintosh (1998). Attentional control theory suggests that anxiety disrupts the top-down/bottom up attention balance, turning attentional bias away from goal-directed information and toward stimulus-driven influences.

Importantly, attentional control theory differentiates between performance *effectiveness* - overall quality of task performance, as indexed by standard behavioural measures such as accuracy - and performance *efficiency* - the relationship between performance effectiveness and the cognitive resources used to maintain the performance level (Eysenck et al., 2007). Thus, it is possible for anxious individuals to maintain a similar level of cognitive performance to non-anxious counterparts while adequate cognitive resources remain available (even though performance efficiency is reduced). As tasks become more difficult (and require more attentional resources, e.g. through high levels of worry in GAD), the increased demand on limited cognitive resources will eventually reduce cognitive effectiveness.

The stimulus-driven attentional system has been further operationalized into three major functions: alerting, orienting and executive functioning (Posner & Peterson, 1990). Alerting is the act of achieving and maintaining an alert state, orienting is the selection of specific information from varied sensory input, and executive functioning is the resolving of conflicts in attentional responses. These attentional subsystems have found to be distinct and separable (Fan, McCandliss, Sommer, Raz, & Posner, 2002).

A major criticism of processing efficiency theory is the lack of specificity regarding central executive function. Miyake et al. (2000) defined three major functions related to the central executive system: *inhibition, shifting* and *updating*. The inhibition function is the use of attentional control to deliberately inhibit automatic responses when necessary, the shifting function is the ability to shift attention from one task to another, and updating is the re-evaluation of internal representations. Using experimental paradigms to isolate each function, it has been confirmed that the three functions are moderately correlated with each other, but definably separate functions (Miyake et al., 2000). Intuitively, attentional control theory implies that anxiety has a greater influence on inhibition and shifting; individuals with greater attentional control are able to withhold attention from task-irrelevant stimuli and allocate attention to the correct goal-oriented task. However, all three functions are interdependent on each other – all rely on central-executive attentional allocation of limited cognitive resources; if resources are reduced (due to excess worrying), then subsequent demands on one function may reduce attentional allocation towards others (Eysenck et al., 2007).

Neurocognitive models of reduced attentional control.

Neurocognitive models of anxiety are in line with Pavlovian models of fear and anxiety (LeDoux, 2000). Animal models suggest that prefrontal inhibitory mechanisms regulate amygdala-driven fear expression (Hartley & Phelps, 2010). In line with biased-competition models of attention (goal- vs. stimulus-driven), common prefrontal-amygdalic mechanisms underlie attentional threat-biases. Increased dispositional anxiety can lead to reduced recruitment of prefrontal control mechanisms, causing selective attention to threat (Bishop, 2007). Additionally, increased state anxiety leads to stronger amygdalic threat-signalling, increasing the valence of stimulus-driven distractors and reducing cognitive resources available for goal-related processing (Figure 1.3).

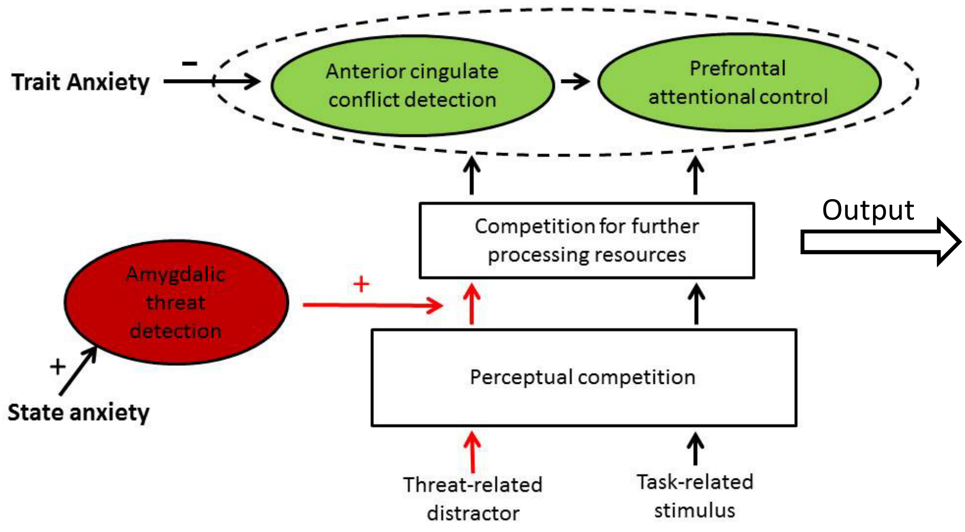

Figure 1.3. Neurocognitive model of anxiety-related biases in selective attention (Bishop, 2007).

While recent neurocognitive and cognitive models emphasize reduced attentional control in anxiety, all biased-information processing models share the notion that selective attention to threat causes reduced cognitive performance. Thus, two experimental predictions can be examined: i) anxiety is associated with deficits in selective attention to threatening stimuli, and ii) anxiety is associated with reduced attentional control.

Evidence for information processing models of anxiety

Initial self-report studies support a link between attentional control and anxiety. Derryberry and Reed (2002) examined a reaction-time task in individuals who completed the Attentional Control Scale self-report measure (ACS; Derryberry & Reed, 2002), while threatening distracter stimuli were presented. High anxious individuals had slower reaction times than low anxious counterparts, but only if they also had low levels of attentional control – indicating that attentional control is related to reduced cognitive performance. Behavioural tasks have been used to try and discern exactly how a reduction in attentional control impacts cognitive performance, by examining threat-related cognitive biases.

Evidence from the Stroop and visual-probe task.

The Stroop task examines cognitive biases, by comparing the speed at which participants can name the colour of emotionally non-threatening words (e.g. utter, alloy) compared to emotionally threatening words (e.g. ulcer, angry), demonstrated in Figure 1.4.

ULCER vs. UTTER

Figure 1.4. Stimuli used in the Stroop tasks, in which participants must name the colours of the stimuli regardless of emotional content.

Anxious individuals are typically slower to identify the colour of threatening words compared to non-threatening words, as they fixate on the threatening stimuli (word content) rather than the non-threatening (word colour). This effect has been observed in social phobia, panic disorder and GAD (see Ruiter & Brosschot, 1994, for a review of the use of the Stroop task). Additionally, effects are notably more robust when the emotional content is relevant to an individual (e.g. 'crowd' for social phobia: Spector, Pecknold, & Libman, 2003) – due to self-perpetuating reinforcement (see Schema Theory). Further manipulations of the Stroop task have found that anxious individuals were slower to identify the colours of emotional words, even if the words were subliminal (i.e. replaced with XXXXX, in the same colour, after < 20ms). This provides evidence for the existence of ‘automatic negative thoughts’ at low-level cognitive processing (Mogg, Bradley, Williams, & Mathews, 1993).

Further to this, a comparison over time of Stroop scores in high-anxious individuals across low-stress and high-stress conditions (high stress was tested one week before exams) found a stronger bias towards threatening stimuli in high-stress conditions (MacLeod & Rutherford, 1992). This supports the notion that increased worry in anxious individuals is self-perpetuating, and negative biases typical of anxiety are stable over time.

However, MacLeod (1999) argues that Stroop scores in HA individuals may not be due to increased attention towards threatening stimuli but, instead, may be due to avoidant processes (attention focused away from the stimuli, resulting in a slower reaction time). Fox (1993) found that anxious individuals showed more Stroop interference even in the absence of threat, suggesting high trait anxiety could be associated with general attentional deficiencies rather than threat-related biases. Furthermore, Mogg and Bradley (1998) suggest that the Stroop task cannot differentiate between increased allocation of attention to threat, or temporarily elevated arousal upon being presented with a threat cue (both would cause a slower response time).

An alternative methodology is the visual-probe task, in which participants are presented with a pair of stimuli (non-emotional vs. emotional) before one of the stimuli is replaced by a dot (demonstrated in Figure 1.5). Participants must determine the location of the dot (left or right stimulus) as quickly as possible. Early findings suggested that anxious participants were faster to respond to a probe in a location following threatening words (vs. location following non-threatening word), while normal participants exhibited similar response times in both conditions (MacLeod, Mathews, & Tata, 1986), consistent with models of biased-attention to threat. Similar studies of individuals with clinical anxiety levels found evidence of attentional bias towards threat in patients with GAD (Mogg, Bradley, & Williams,1995) and panic disorder (Mathews, Ridgeway, & Williamson, 1996).

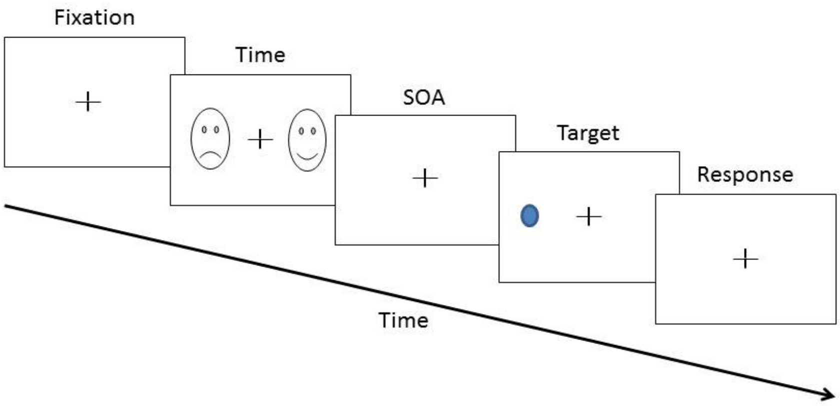

Figure 1.5. A visual dot-probe trial, measuring response times for participants to determine the location (left or right) of a probe stimulus immediately following threatening or non-threatening stimuli presented for various stimulus onset asynchrony (SOA)

Other variants of the visual-probe paradigm used visual stimuli rather than words, to avoid potential confounding effects (e.g. semantic processing biases when reading words). Mogg, Philippot and Bradley (2004) examined attentional biases in a clinical sample with social phobia, presenting angry, happy and neutral faces at 500 ms and 1250 ms durations. Participants only demonstrated an attentional bias for threat in the short, 500 ms presentation. While providing strong evidence for biases in the early-stages of processing in HA individuals, these results indicate that a slightly later stage of emotional processing also occurs.

Similar dot probe studies found HA individuals had faster responses to visual probe RTs when it was presented after household objects rather than after emotional faces, (presented for 500 ms; Chen, Ehlers, Clark, & Mansell, 2002). Although, seemingly in contrast with other evidence from the dot-probe task (such as Mogg et al., 2000), Mogg et al. (2004) suggest the existence of a ‘vigilant-avoidant’ response tendency, in which after the initial hypervigilance to threat, HA individuals direct their attention away from threat after more elaborative processing. While consistent with the existence of a threat-valence evaluation mechanism, such findings are reflective of the issue that the dot probe task only provides a ‘snapshot’ of attentional bias at singular exposure durations and is therefore unable to provide detail of the interaction between different levels of processing. Furthermore, it has demonstrated mixed test-retest reliability: Mogg and Bradley (1999) closely replicated findings that HA individuals were quicker to identify threatening faces and slower to identify happy faces (Bradley, Mogg, Falla, & Hamilton, 1998), but Cooper et al. (2011) found that attentional biases to emotional facial expressions were entirely inconsistent in terms of their relationship to anxiety [induced in a robust experimental model]).

While the visual-probe and Stroop tasks cannot specify the exact nature of threat-related attentional biases, a meta-analysis of 172 studies found consistent findings across both the Stroop task and the dot probe task in clinically anxious, and non-clinical HA individuals (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007). Supraliminal exposure in the Stroop task (i.e. presented for a long enough time period for participants to engage in complex processing) caused threat-avoidance, whereas subliminal visual-probe studies demonstrated strong threat-vigilance in anxious individuals. This evidence suggests that anxiety-related deficits in cognitive functioning are due to both early and late-stage stimulus processing.

Fox, Russo and Dutton (2002) examined the time it took for HA individuals to find a target presented in a different location to emotional face cues (vs. LA individuals). HA participants took longer to find the cue for emotional (vs. neutral) faces, while LA times were similar across emotion. The same research group found that high anxious individuals were slower to disengage from threatening stimuli (vs. neutral stimuli) but stimuli valence had no effect in attracting attention to their location (Fox, Russo, Bowles, & Dutton, 2001). This evidence that anxiety causes delayed disengagement from threat (but not initial hypervigilance towards threat) caused the authors to call for tasks that could decompose different attentional functions.

Evidence from the attention network test and antisaccade task.

Hallett (1977) presents a conceptually sound behavioural measure of attentional control in the anti-saccade task, with good test-retest reliability (Klein & Fischer, 2005). Using directional instructions, individuals are asked to exercise top-down attentional control to suppress a reflexive saccade towards an abrupt peripheral stimulus. A pro-saccade task is also performed, in which individuals are asked to look towards the abrupt stimuli, therefore eliminating the volitional-reflexive conflict (Figure 1.6). Comparison of the two tasks therefore provides a measurement of inhibition and shifting attentional functioning, it being expected that HA individuals would have reduced cognitive functioning.

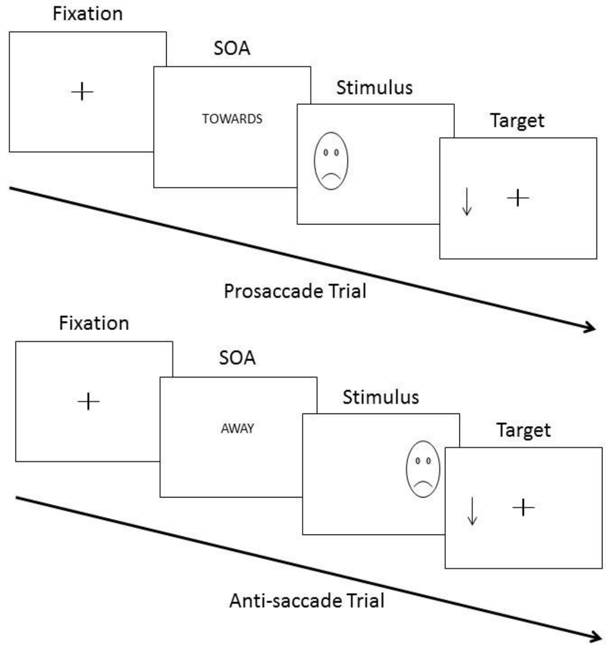

Figure 1.6. Pro-saccade and anti-saccade trials in the anti-saccade tasks. Participants are instructed to look towards or away from a stimulus, demonstrating the reflexive control of their automatic eye movements (Hallet, 1978).

Importantly, Olk and Kingstone (2003) propose that the anti-saccade task also allows behavioural differentiation of cognitive effectiveness (the error rate of the antisaccade task reflects cognitive ability to override reflexive responses) and efficiency (increased correct anti-saccade latencies reflect additional processing resources used to inhibit these responses; greater trial latency indicates reduced efficiency). Thus, results such as those of Calvo, Eysenck, Ramos, and Jiminez (1994), in which HA participants displayed greater cognitive effort but similar levels of performance to their LA counterparts, would be demonstrated by greater correct anti-saccade latency in HA individuals, but with no differences in error rate.

Experimental evidence has supported this theory; in a simple anti-saccade task using neutral, oval stimuli, HA individuals had an increased response latency compared to LA participants, with no differences in error rate (Derakshan, Ansari, Hansard, Shoker, &

Eysenck, 2009). However, a task version using threatening stimuli (therefore placing increased cognitive demands on anxious participants who have to volitionally ignore a threat-response attentional bias) found an increased error rate in HA participants compared to LA (M Garner, Ainsworth, Gould, Gardner, & Baldwin, 2009).

A mixed antisaccade task, in which participants were required to randomly shift from anti-saccade to pro-saccade tasks, found that HA individuals were less able to utilise attentional control to efficiently shift attentional resources according to new task demands (Ansari, Derakshan, & Richards, 2008). Functional magnetic-resonance imaging (fMRI) studies indicate that anti-saccade performance reflects increased prefrontal context (PFC) activity (Ettinger et al., 2008) – participants demonstrated increased ventrolateral (vlPFC) and dorsolateral (dlPFC) activation during the task, with sustained activation throughout the entire duration of each trial - rather than at specific occurrences of inhibition/volitional attention. However, the fMRI antisaccade analysis involved trials taking up to 12s; possibly allowing other, more complex cognitive functions to confound results. A more temporally accurate imaging study monitored evoked-response potentials (ERPs) during a fixation period in which participants were instructed to make either a pro- or anti-saccade; compared to an LA control group, HA individuals demonstrated increased activity in pre-frontal cortical regions (Ansari & Derakshan, 2011). For a summary of antisaccade findings across anxiety, see Ainsworth and Garner (2013).

Outside of the antisaccade task there is further evidence supporting attentional control theory; Christopher and MacDonald, (2005) used a variety of behavioural tasks examining the different facets of working memory (phonological loop examined using word length task, visuo-spatial sketchpad examined using grid recognition task, central executive examined using backwards letter span) and found an effect of anxiety (STAI scores) only on the central executive. The same trend was found using the Corsi Blocks test (Eysenck, Payne, & Derakshan, 2005).

Additionally, central executive subsystems have been examined using the Attention Network Task (ANT; Fan, McCandliss, Sommer, Raz & Posner, 2002), a measure with good test-retest reliability (Fan et al., 2002). In the ANT, participants are asked to determine the direction of an arrow amongst congruent and incongruent distractors, with separate output measures of alerting (achieving/maintaining readiness for action), orienting (preferential selection of certain information channels) and executive attention (conflict resolution of competing information responses). While original analysis suggested no correlations between the three attention network functions (Fan et al., 2002), a recent analysis of 15 data-sets has suggests that network functions are related (Macleod et al., 2010). Experiments using the ANT found that trait anxiety was related to deficiencies in the executive function but not in alerting or orienting (Pacheco-Unguetti, Acosta, Callejas, & Lupiáñez, 2010), while higher state anxiety is associated with increased alerting performance (Dennis, Chen, & McCandliss, 2008).

Evidence across a variety of behavioural and neuroimaging tasks supports the idea that appropriate allocation of attentional resources is a crucial factor in performance during cognitive tasks. The crucial role of the central executive in cognitive functioning has implications for both cognitive biases of selective attention and threat-appraisal in anxious individuals.

Neurocognitive evidence for cognitive anxiety models

Investigation of neuro-cognitive functioning has provided evidence for cognitive anxiety model, predominantly revolving around prefrontal inhibition of amygdalic fear-responses. Preliminary studies used conditioned fear responses to examine prefrontal and amygdalic activity in animals and humans (see Bishop (2007) for a review). Crucially, early investigation of conditioned fear responses in dogs found that any diminution in fear of particular stimuli gradually reduced over long time periods, indicating that rather than being extinguished, conditioned fear responses were inhibited (Pavlov, 1927; in Quirk & Mueller, 2008).

This inhibition is thought to occur in prefrontal mechanisms; lesioning of medial prefrontal cortical (mPFC) areas in rats has been shown to disrupt fear-response inhibition, with no effect on the original acquisition of a freezing response (Morgan, Romanski, & Ledoux, 1993). Notably, similar lesions had no effect on the extinction of a conditioned startle response (Gewirtz, Davis, & Falls, 1997), possibly due to the different strength of association between the freezing response and the startle response. However, prefrontal down-regulation of amygdalic activation has been demonstrated in multiple studies; Phelps, Delgado, Nearing, & LeDoux (2004) found increased prefrontal activation after extinction training and Milad et al. (2007) found a significant positive correlation between vmPFC activation and the magnitude of extinction retention using fMRI techniques.

Miller and Cohen (2001) argue that the PFC’s primary function is ‘top-down biasing’; that is, the prioritising of correct sensory input needed to achieve our goals. In anxious individuals, therefore, increased attention to threat would be characterised by reduced PFC activity (reduced ‘top-down biasing’) and increased amygdalic function. fMRI studies show that those with increased amygdalic activity are more likely to suffer anxiety disorders such as post-traumatic stress disorder (PTSD) or specific phobias, and PTSD sufferers have demonstrated amygdalic hyper-responsivity during conditioned fear-response acquisition (Shin, Rauch, & Pitman, 2006).

In line with neurocognitive models, neuroimaging studies of selective attention to threat have focused on both amygdala and PFC activity. Amydala activity increased when individuals attended to emotional faces (vs. non-emotional faces) surrounded by distractor stimuli. When participants were asked to attend to distracter stimuli surrounding the faces, no differences in activity were noted – indicating that attention modulates amygdalic functioning (Pessoa, McKenna, Gutierrez & Ungerlieder, 2005). In contrast, Anderson, Christoff, Panitz, Rosa and Gabrieli (2003) asked participants to alternatively attend a fearful/neutral face, or distractor stimuli. When attending the distractor stimuli, which were transparent and overlaid on the emotional faces, amygdala activity still increased in the fearful face condition. Moreover, LA and HA participants who were presented with images of pairs of houses and fearful/neutral faces (Bishop, Duncan, & Lawrence, 2004) both demonstrated increased amygdala response to attended threat-related stimuli, but only HA participants demonstrated increased activity to unattended threatening stimuli.

While studies of prefrontal activity are limited in comparison to examination of the amygdala, results support the framework of dysfunctional prefrontal inhibition. When participants were asked to identify whether two neutral stimuli were identical, in the presence of threatening distracter stimuli (fearful faces), those with higher anxiety showed less ACC and PFC activation (Bishop, Duncan, Brett, & Lawrence, 2004), and HA individuals demonstrated reduced prefrontal recruitment (vs. LA counterparts) during a letter-search task (Bishop, 2009).

Evidence in both cognitive, experimental paradigms and functional imaging studies has demonstrated the critical role of attention control in anxiety. A dysfunctional relationship between the amygdala and PFC systems represents a failure to control processing to support the inhibition of threat-related representations and/or the activation of alternate non-threat-related representations.

Consistent with predictions from early (i.e. emphasis on biased threat-processing) and recent (emphasis on reduced attentional control) models of anxiety, there is convergent evidence of anxiety-related biases in selective attention to threat (initial orienting, delayed disengagement), threat inhibition (antisaccade) and attention control more broadly (antisaccade and ANT). Therefore, it seems intuitive that treatment and protection against anxiety disorders may be well served by approaches which explicitly target dysfunctional attentional mechanisms – such as mindfulness.

Mindfulness: a promising treatment for anxiety?

Improving psychological interventions for anxiety

Pharmacological measures have demonstrated efficacy in the treatment of anxiety disorders, especially when used in conjunction with cognitive-behavioural therapy (CBT). Selective serotonin reuptake inhibitors (SSRIs), tricyclic antidepressants, monamine oxidase inhibitors, and benzodiazepines have all been shown to reduce anxiety symptoms (Baldwin et al., 2005). However, there are many limitations to pharmacological treatments. Children, adolescents, pregnant/breastfeeding women and the elderly are often unable to tolerate an extensive list of possible side-effects – including sleep disruption, weight gain and sexual dysfunction (Ferguson, 2001).

Cognitive behavioural therapy (CBT), focuses on the correction of cognitive biases and reduction of dysfunctional behaviours (e.g. safety behaviours/avoidance). Meta-analysis suggest that CBT has broad efficacy in acute and particularly long-term magnagement of anxiety symptoms (Butler, Chapman, Forman, & Beck, 2006). However, relapse-rate is still high and residual symptoms remain in many individuals (Ninan, 2001). Furthermore, many clinical practitioners report poor confidence in CBT techniques and the associated financial costs of delivery limit its availability (Baldwin et al., 2005).

Evidence for the integration of cognitive bias modification into anxiety treatment

Cognitive-bias modification (CBM), originally developed for researchers to experimentally manipulate cognitive biases, uses cognitive tasks to expose individuals to selective attention and biased interpretation processes according to task contingencies. For example, an individual who repeatedly completes a visual-probe task in which the target is always behind a positive emotional face implicitly learns a trained bias towards positive emotional faces (learned attention bias). Similarly, a task requiring individuals to insert the last phrase in an emotionally ambiguous story, yet which always reveals a 'happy ending', would implicitly train a positive interpretation bias (see Bar-Haim, 2010, for a more detailed summary).

Early CBM research used negative task contingencies to induce negative cognitive biases in healthy individuals, finding that self-report measures of anxiety and depression increased (Mathews & Mackintosh, 2000; Wilson, MacLeod, Mathews, & Rutherford, 2006), and more recent studies have attempted to reduce negative biases. While many have been successful in inducing attentional biases as measured by cognitive tasks, a number of meta-analyses have found moderate evidence for small reductions in subjective anxiety (Beard, Sawyer, & Hofmann, 2012; Hakamata et al., 2010; Hallion & Ruscio, 2011).

Heeren, De Raedt, Koster and Philippot (2013) suggest that CBM is consistent with (neuro)cognitive models of anxiety – interpretation biases reduce threat-appraisal processes, while attention-bias modification reduces maladaptive attention to threat. In line with this, CBM has been shown to have relevant evidence for GAD sufferers. High-worriers who completed a positive-contingency biased visual-probe task had reduced thought intrusions in a worry task (Hayes, Hirsch, & Mathews, 2010). Recently, GAD patients who completed an interpretation-bias task (participants repeatedly accessed benign meanings of ambiguous homophones with one letter missing, e.g. 'batter f_sh') had reduced negative thought intrusions in a breathing task (Hayes, Hirsch, Krebs, & Mathews, 2010). A study using two tasks (encourage/discourage threat-vigilance and encourage/discourage threat-disengagement) found that reductions in worry-intrusions only occurred when threat-vigilance was reduced (Hirsch et al., 2011).

Brosan, Hoppitt, Shelfer, Sillence and Mackintosh (2011) noted the need for careful translation of experimental research tasks for potential use in clinical treatment programs. Implications of implementing CBM into existing CBT programs are only recently being considered. It remains to be seen whether modifications to existing cognitive therapy interventions – targeting volitional, strategic cognitive processes – can affect the short-term, involuntary processing involved in attentional biases (Mobini & Grant, 2007). A pilot study of six 90-minute weekly sessions of attention management training in patients suffering from chronic pain found self-report decreases in hypervigilance to pain and pain-related anxiety (Elomaa, De C Williams & Kalso, 2009). Attention management in the study was practiced using breathing exercises to practice non-judgemental attention; participants were asked to be aware of thoughts, images and bodily sensations without reacting to or following them – practices based on mindfulness techniques introduced by Kabat-Zinn (1990).

What is mindfulness?

Over the last two decades, 'mindfulness' training has become increasingly common across various clinical environments. With roots originating in Buddhist meditation practices (often linked to the Pali term *sati*, denoting 'awareness, attention and remembering'), mindfulness is typically defined as "paying attention in a particular way: on purpose, in the present moment, and non-judgementally" (Kabat-Zinn, 1990). An intuitive link can be drawn between this definition and aspects of attention (present moment/on purpose) and emotion regulation (non-judgmental interpretation of threat). The rapid spread of mindfulness approaches has led to a range of methods and meditative techniques, all of which focus on training attention in order to reduce thoughts and cognitive processes that are not goal-related (Chiesa, Serretti, & Jakobsen, 2013; Chiesa, Calati, & Serretti, 2011; McRae, Misra, Prasad, Pereira, & Gross, 2012). Due to its elaborate background, a detailed summary of the history of 'mindfulness' is beyond the scope of this thesis, but see Siegel, Germer and Olendzki (2009) for an account of its translation from ancient, Eastern tradition to a third-wave Western clinical intervention (in Didonna, 2009).

Self-report studies have found that individuals with higher levels of dispositional mindfulness have significantly higher pleasant affect, vitality, life satisfaction, self-esteem and optimism (Brown & Ryan, 2003; Prazak et al., 2012), and associations between higher mindfulness and reduced autonomic arousal have been observed (i.e. heart-rate variability; Burg, Wolf, & Michalak, 2012). A pilot study also found a beneficial psychological effect of 6 one hour sessions of mindfulness training (vs. guided imagery) on pain tolerance in healthy undergraduates (Kingston, Chadwick, Meron, & Skinner, 2007).

Recently, the development of more formal, structured programs such as Mindfulness-Based Stress Reduction (MBSR; Kabat-Zinn, 1990) and Mindfulness-Based Cognitive Therapy (MBCT; Segal, Williams, & Teasdale, 2003) have further increased the use of mindfulness interventions particularly for emotional problems. MBSR and MBCT are experiential learning programmes, usually involving weekly group meetings and daily individual practice over an 8-week period. MBCT was developed with additional exercises developed to prevent relapse in individuals with depression, although has since been modified to be used across other psychological disorders, such as GAD (Burke, 2009; Rubia, 2009). In a meta-analysis of empirical MBSR studies, it was noted that existing MBSR protocols varied widely in style of mindfulness meditation administered, as well as differences in procedural application, as would be expected in studies of 'working' clinical trials (Grossman, Niemann, Schmidt, & Walach, 2004). However, the authors noted a range of effect sizes (*d*s .25 to 1.01, $d_{average} = .50$, $p < .001$) across a broad range of disorders and problems, such as depression, anxiety, coping style, chronic pain and physical well-being. Meta-analysis of MBCT programmes showed mixed results and Coelho, Canter, & Ernst (2007) note difficulties in isolating specific effects of MBCT within often complex treatment programmes, and that improvements can be made in reporting analyses. However, investigations within strict experimental conditions has found effects of MBSR-related therapies on major depressive disorder (Ma & Teasdale, 2004), attention-deficit hyperactivity disorder (Zylowska et al., 2008) and GAD (Evans et al., 2008). A recent meta-analysis of 36 RCTs found 25 cases of superior outcomes in the meditation group compared to control group, although the authors noted that most studies only measured improvements in anxiety symptoms rather than anxiety disorders as clinically diagnosed (Vøllestad, Nielsen, & Nielsen, 2012).

Further investigations within non-clinical populations have found effects of mindfulness meditation interventions within cognitive constructs relevant to attention and emotion regulation. After a 10-day intensive mindfulness course, 20 novice meditators demonstrated improvements in self-reported mindfulness, working memory and sustained attention (measured by reaction time in an internal switching task) compared to a control group who had no mindfulness training (Chambers, Chuen Yee Lo, & Allen, 2007).

While mindfulness treatments have been linked to major depressive disorder (Ma & Teasdale, 2004), attention-deficit hyperactivity disorder (Zylowska et al., 2008) and GAD (Evans et al., 2008), the exact nature of the mindfulness/anxiety relationship still needs clarification. Clark and Beck (2010) comment on the reliance of clinicians on personal experience, which can conflict with empirical evidence. Investigation of the mechanisms involved in mindfulness meditation will provide accurate, in-depth knowledge of the implications it holds for cognitive bias modification in anxious populations.

Recent work has highlighted the importance of such an approach, and that elucidating putative mechanisms of action in mindfulness interventions will improve theoretical understanding of how this relatively new treatment works, and provide an opportunity to enhance efficacy via emphasis of these mechanisms. Similar mechanistic approaches have examined psychological and neural mechanisms by which mindfulness can reduce depression vulnerability (see Paul et al, 2013) and disrupt alcohol dependence (see Garland, Gaylord, Boettinger & Howard, 2010). Although meta-analyses have found moderate effect sizes in reducing clinical anxiety symptoms (Hedges' $g = .53$ for waitlist controls, .55 for pre-post comparisons; Khoury et al, 2013), there is still relatively little compelling evidence regarding specific mechanisms of change, particularly in targeted mindfulness interventions such as MBSR or MBCT (Kuyken et al., 2010).

Critically, it will help to provide a basis for the development of effective treatments and a theoretical understanding of how mindfulness meditation treatments may augment existing cognitive-behavioural and pharmacological methods. These seemingly efficacious treatments have been developed without the associated empirical examination that usually accompanies them, causing a need for robust empirical studies with rigid, transparent methods, to promote standardized intervention formats and better inform the growing number of individuals who practice mindfulness regularly (see Halliwell, 2010). However, the transitional nature of mindfulness, stemming from an ancient Buddhist meditational method in the East towards becoming a standardized cognitive-behavioural therapy in the West is far from complete, and there remains a need to establish clear operational definitions of mindfulness and its component processes (see Shapiro, Carlson, Astin & Freedman, 2006; Holzel et al., 2011).

Defining the concept of mindfulness

While mindfulness was originally described by Kabat-Zinn (1990) as "paying attention in a specific way: on purpose, in the present moment, and non-judgementally", Brown and Ryan (2004) highlight the need for accurate theoretical and operational definitions of constructs that provide the basis for salient treatment methods. They critique one of the more enduring mindfulness conceptualizations: a two-component model involving (i) self-regulation of attention towards immediate experience and (ii) attitude of curiosity and acceptance towards these immediate experiences (Bishop et al., 2006). This is a conceptualization that intuitively leans towards the 'sati' (awareness, attention, remembering) origins of mindfulness. Bishop et al. noted the associations often made between mindfulness and bare awareness, arguing that attitude brings a qualitative aspect to this awareness – bringing curiosity and openness to attention rather than a degree of clinical dissociation. This 'orientation to experience' may protect against attentional increases causing non-beneficial attentional biases.

The two-component model is reflected in several current self-report measures of mindfulness (e.g. Kentucky Inventory of Mindfulness Skills; Baer, Smith, & Allen, 2004), which attempt to reconcile awareness and attitude aspects of mindfulness. Recent evidence that suggests that attention/awareness may operate through distinct mechanisms that lead to individual differences in mindfulness (Holzel et al., 2011; Ruocco & Direkoglu, 2013). However, it can be argued that the deployment of an attitudinal framework (i.e. curiosity and openness) towards current attention is at odds with the concept of completely objective perception – a contradiction typical of the quickly evolving paradigm of mindfulness (see Grossman, 2011).

A more recent model introduced a third factor, proposing mindfulness as a complex interaction between *intention, attention* and *attitude* (Shapiro et al., 2006). Shapiro et al. propose that the inclusion of intention (i.e. why an individual is practicing) is crucial to the efficacy of the process, and often overlooked in other definitions. The reason why an individual practices is an often-overlooked, central component to mindfulness, which is dynamic and evolves through practice cycles (Shapiro, 1992). However, they also note that the role of attention is at the core of mindfulness, and the cognitive basis for a comprehensive empirical framework allowing for sophisticated analysis. Brown and Ryan (2004) suggest that the attitudinal aspects of mindfulness have reduced relevance in modern empirical settings, and have recently suggested that 'sati-based' attentional aspects are most relevant for building basic knowledge and refining effective interventions (Brown, Ryan, Loverich, Biegel, & West, 2011; in reply to Grossman, 2011).

The relationship between meditation and attention

Lutz, Slagter, Dunne and Davidson (2008) examined the attentional components of meditation techniques (that therefore may be applicable to mindfulness) and made a distinction between open-monitoring and focused attention. These separate, defined constructs both emphasise paying attention 'in a particular way' and may provide insights for mindfulness training. Open-monitoring meditation involves a non-reactive monitoring of the environment as it is experienced from moment-to-moment, with no explicit attentional focus (similar to the attention characterised by openness and curiosity), whereas closed-focus meditation involves skills such as disengaging from distractors and directing and engaging attention towards the intended object ('on-purpose' and 'in a particular way'). More recently, two aspects of meditation ('focused attention' and 'open-monitoring meditation') have been proposed to translate onto the more established 'awareness' and 'attitude' facets of mindfulness respectively (Perlman, Salomons, Davidson & Lutz, 2011).

Focused-attention (FA) practice consists of sustaining selective attention on a chosen object (often a localised sensation, such as breathing patterns), and monitoring this focus for any distraction and wanderings. Should distraction occur, FA involves recognition of the wandering, and restoring attention to the initial object. Concordantly, FA practices attention-network skills commonly used in cognitive functioning: monitoring and alerting, and executive functioning skills of inhibition and switching (see Eysenck et al., 2007). As practitioners become more experienced, they become more adept at inhibiting the wandering attention, with reduced cognitive effort (thereby increasing their cognitive efficiency). Carter et al. (2005) presented Buddhist monks with two competing stimuli using binocular rivalry (i.e. one image presented to each eye), and asked them to focus on one image only. Those proficient in 'one-point' attention reported large (50%) increases in the stabilization of their perceptual focus– with some participants reporting total dominance (with no effect of distractors) immediately after a 20-minute session of 'one-point' meditation. Other experienced meditators asked to engage in 'compassion meditation' and individuals not experienced in any form of meditation showed no change in their perceptual rivalry reports. Brefczynski-Lewis, Lutz, Schaefer, Levinson and Davidson (2007) examined neural correlates of one-point sustained attention by asking individuals with different levels of meditation to focus their attention in a number of sessions while distractor stimuli (noises) occurred during and between sessions. Using fMRI, they found that brain activation in prefrontal regions associated with attention was greater in intermediate meditators than novices, but expert meditators had on average reduced activation. Further analysis suggested that expert meditators had reduced brain activation to emotions and discursive thoughts (experimentally associated with distractor noises) and increased activity in the frontal regions related to attentional inhibition – suggesting that a degree of plasticity in the attentional neural networks increases with meditation experience.

Unlike FA, open-monitoring of the environment (OM) involves no explicit focus and no deliberate deselection of environmental, distractor stimuli, particularly regarding bodily sensations – such as pain. Instead, individuals must monitor the environment while maintaining a consistent emotional and cognitive state. The central aim of OM meditation is to enable individuals to gain a clear, reflexive awareness of usually implicit cognitive mechanisms – potentially allowing the halting of dysfunctional non-goal-related cognitions and a subsequent reduction in their occurrence. A study giving participants a short-course (5 x 20 minute sessions) of OM training found improvement in executive attention (reduced distractor interference) using the Attention Network Task compared to those who were given similar relaxation sessions (Tang et al., 2007). However, Lutz et al. (2008)

suggests that OM is a progression of FA, as those skilled in FA gradually reduce the focus on an explicit object, and emphasize monitoring for distractor stimuli.

Evidence for a relationship between mindfulness-based training and attention

There are obvious parallels between mindfulness and the functional cognitive techniques involved in both OM and FA, such as enhanced focus on the present moment and internal cognitive processes (such as volitional attentional control). Indeed, both MBSR and MBCT incorporate elements of both attentional facets throughout their 8-week timescale, even within their most directly mindfulness-related components (Perlman, et al., 2011). Perlman et al. note the importance of differentiating between FA and OM in experimental methodology in conclusively establishing mechanisms that lead to mindfulness-meditation related benefits. To this end, experimental findings examining explicit aspects of mindful attention (or those inherently translatable to concepts of FA and OM) can inform clinical interventions.

A number of studies have predicted positive effects of mindfulness meditation, as well as dispositional mindfulness, on attentional functions. Jha, Krompinger and Baime (2007) examined ANT performances in novice and expert meditators. Novices were given an 8-week MBSR course, and expert meditators took part in a 1-month intensive mindfulness retreat (vs. ANT scores in novices with no training). Before any training took place, there were no differences between novice groups, but expert meditators had better executive attention function (although the lack of dispositional mindfulness measures means prevents this being firmly attributed as a mindfulness-related difference). After training (at time 2), the novices in the MBSR group had improved orienting, perhaps due to increased goal-related attentional control. Additionally, alerting function of the expert meditators also increased – possibly due to mindfulness training allowing the progression of bottom-up attention once top-down goal-related attentional control was intuitive and natural (in a similar manner to the progression from FA to OM, described earlier). However, mindfulness meditation practice had an effect on each attentional network function: alerting, orienting and executive control. The following section will examine evidence for the impact of mindfulness on each function separately (studies included are summarised in Table 1.1, Appendix A):

Executive Attention. Buddhist meditators who are well practiced in mindfulness techniques (compared to naïve controls) report greater dispositional mindfulness in self-report measures, and demonstrate increased performance on Stroop tasks that require executive control to inhibit conflicting word/colour conflict (Moore & Malinowski, 2009; Teper & Inzlicht, 2013). Similarly Tang, Yang, Leve and Harold (2012) reported that short-term mindfulness intervention (IMBT) increased executive functioning, and a brief mindfulness intervention (3 total hours over 28 weeks) elicited improvements in Stroop task performance alongside a pattern of reduced electrocortical activity typically associated with increased attentional control (increased N2/decreased P3 components; Moore, Gruber, Derose, & Malinowski, 2012, decreased prefrontal activity; Farb, Segal, & Anderson, 2013).

A 10-day intensive mindfulness retreat for novice meditators (vs. comparison group with no training) improved performance on an internal switching task (Chambers et al., 2007), and three months of intensive meditation training improved detection of a target stimuli presented immediately after a distractor stimuli in 17 healthy individuals, as well as reduced attentional allocation towards the distractor (Slagter et al., 2007). A study using the N-back task, in which digits are presented in consistent intervals and participants are asked to recall the digit presented N intervals previously (i.e. hold N numbers in WM) found mindfulness-training increased task performance (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). However, Zeidan et al. hypothesized an increase in N-back speed, indicating greater processing efficiency (rather than effectiveness), which was not observed. Additionally, a randomized control study of 150 individuals assigned to either mindfulness training, relaxation training or a neutral task, found no effect of mindfulness meditation on any attention network function, measured using the ANT (Polak, 2009). This may be due to the short nature of the mindfulness intervention (2 sessions lasting 15 minutes) before they completed a Stroop task and the ANT. Furthermore, Anderson, Lau, Segal and Bishop (2007) found no effect of an 8-week MBSR course on attention switching or inhibition (measured using the ANT). A behavioural study using the 'PASAT-C' task – designed to measure processing speed and attention (see p42) – found no effect of MBSR on attention scores (Ekblad, 2009), although the author noted that the ill-defined construct of mindfulness required a more specific, focused task to isolate individual aspects of attention rather than a general 'attention and processing' behavioural score. This sentiment was supported by Lykins, Baer and Gottlob (2010) who examined performance on a number of widely-used measures of attention function and working memory in experienced meditators vs. demographically-matched non-meditators, and found no performance differences in any measures of attention, despite substantial differences in dispositional mindfulness between the two groups.

Further evidence comes from dichotic listening tasks, in which participants who received mindfulness training were better at focusing on target tones over simultaneous distracting tones (three months of intensive meditation training: Lutz et al., 2009; one month intensive mindfulness retreat: van Vugt & Jha, 2011), and diffusion tensor imaging (DTI) findings showing that 11 hours of meditation training over a one month period increased ACC white-matter connectivity (Tang et al., 2010). Overall, convergent evidence suggest mindfulness increases executive attention, but more rigorous study is needed to clarify this association.

Orienting and Alerting. Evidence for the effect of mindfulness on orienting and alerting is less frequent. Participants who took part in an 8-week MBSR course emphasizing concentrative attentional skills demonstrated increases in orienting function on the ANT task (vs. no-intervention controls; Jha, Krompinger & Baime, 2007). However, Jha et al. also examined experienced meditators (mean 60 months experience) who took part in a 1-month intensive retreat (10-12h per day). Before the intervention, the retreat group showed no significant orienting advantage over either naive group (together or separately), and did not show the improvements in orienting of the MBSR group. The retreat group did show a positive correlation between alerting function and mindfulness experience at Time 2 (r = .52), with more meditation experience associated with better alerting. However, neither MBSR nor retreat groups' alerting significantly improved during the interventions. Jha et al. noted the need for further research to confirm the degree to which attentional changes in relatively short mindfulness interventions (e.g. MBCT or MBSR) are relatable to differences observed between experienced and naive practitioners.

Van den Hurk, Giommi, Gielen, Speckens and Barendregt (2010) found that experienced meditators had increased ANT orienting function, compared to naïve controls with no meditation experience. Furthermore, individuals who took part in a one-month MBSR course showed a reduction in rumination and distraction compared to controls that either took part in no intervention or relaxation therapy, indicating an increase in the ability to maintain focus on selective information (Campbell, Labelle, Bacon, Faris, & Carlson, 2012), consistent with recent findings that individuals receiving mindfulness training are able to maintain more specific life goals (Crane, Winder, Hargus, Amarasinghe, & Barnhofer, 2012). Semple (2010) found that a 4-week mindfulness intervention caused significant improvements in discrimination skills in a signal-detection task (participants had to identify the letter X when it followed the letter A, but not when it followed any of 12 other letters commonly presented) vs. wait-listed controls and progressive muscle relaxation therapy. However, Polak (2009) found no effect of two brief (15-minute) mindfulness sessions on the orienting or alerting network functions This may be explained by recent evidence that orienting and alerting network measures in the ANT are not as reliable as the measure of executive attention (see Macleod et al., 2010, for a review), although mindfulness-based training (12 one-hour sessions over 24 weeks) did not improve measures of visual attention searching in school-children (Napoli, Krech, & Holley, 2005). The limited evidence for the efficacy of mindfulness interventions on orienting and alerting is, however, arguably in line with theoretical models of mindfulness. The next section will consider the extent to which mindfulness may modulate biased threat-processing.

The relationship between mindfulness and emotion processing

With an established relationship between mindfulness and top-down regulation of general (non-emotional) cognitive resources, this next section examines whether individual differences in dispositional mindfulness are related to the regulation of negative emotion. Cognitive models of anxiety contain emotion-processing elements (e.g. Valence Evaluation System: Mogg & Bradley, 1998) that are dysfunctional in anxiety disorders (Bar-Haim et al., 2007). Mechanisms of attentional control within emotion-processing are increasingly viewed as maladaptive executive control mechanisms reflecting biased prefrontal regulation of amygdalic threat-responses (e.g. selective attention to threat, and attention to distracting stimuli; see Ochsner & Gross, 2005), consistent with current neurocognitive models of reduced attentional control in anxiety (Bishop, 2007).

There are also several strategies to modulate dysfunctional emotional responses through emotional reappraisal (i.e. reinterpreting events and inhibiting automatic negative responses) that have been shown to reduce negative affect using both self-report and psychophysiological measures (see Ochsner & Gross, 2008, for a review). Ochsner, Bunge, Gross & Gabrieli (2002) suggest that during such reappraisal executive control processes are required in the ‘interpretation manipulation’, reflected in decreased amygdala activation during reappraisal (vs. ‘passive observation’ trials).

Thus, mindfulness-related attentional benefits (i.e. increased executive control) may also benefit and correct biased emotion-processing in anxiety. Those with greater levels of mindfulness, having an objective, non-judgemental awareness, may be able to engage in 'metacognitive insight', whereby thoughts are perceived to be transient, insubstantial mental events rather than accurate representations of reality (Bishop et al., 2004). This may therefore reduce worrying thoughts, as there is less opportunity for negative elaborative processing.The Cognitive and Affective Mindfulness Scale - Revised (CAMS-R) is a mindfulness scale investigating aspects of mindfulness relevant to adaptive emotion regulation (Feldman, Hayes, Kumar, Greeson, & Laurenceau, 2006). The CAMS-R has shown strong correlations with both existing mindfulness measures (such as the Mindfulness Attention Awareness Scale; Brown & Ryan, 2004) and measures of 'emotional intelligence' such as the Trait Meta-Mood Scale (TMMS; Saveloy, Mayer, Goldman, Turvey, & Palfai, 1995). However, no explicit relationship between emotional intelligence and dispositional mindfulness was reported. A recent cross-sectional study investigated the role of dispositional mindfulness in reducing worrying thoughts induced by negative affect (Gilbert & Christopher, 2009). In low-mindfulness individuals there was a strong relationship between depressive affect and negative cognitions, but not in high-mindfulness individuals. The authors suggest that metacognitive insight may allow individuals to hold a degree of detachment to maladaptive cognitions, although they note the cross-sectional study design may have potential confounds.

In line with this, recent studies cross-sectional studies suggest that experienced mindfulness practitioners have reduced self-referential processing compared to novices (Berkovich-Ohana, Glicksohn, & Goldstein, 2012), and fear of negative evaluation was negatively related to dispositional mindfulness throughout a CBT intervention for Social Anxiety Disorder (Burton, Schmertz, Price, Masuda, & Anderson, 2013). An investigation using self-report measures found dispositional mindfulness to be negatively associated with attentional control, and that the best predictor of mindfulness was low trait anxiety (Walsh, Balint, Smolirasj, Fredericksen, & Madsen, 2009).

Studies using behavioural measures to examine the effects of mindfulness on emotion regulation are infrequent. Arch & Craske (2006) randomly assigned individuals to a 15-minute unfocused attention exercise, a 15-minute instructed worry exercise or a 15-minute mindfulness-breathing exercise, and presented positive, negative and neutral-valenced images. After interventions, the mindfulness group demonstrated reduced negative affect in response to the negative images compared to the other groups, as well as higher positive affect to the positive slides. They also reported greater willingness to view optional negative stimuli, indicating that they were able to reappraise their initial negative experience. This finding is in line with evidence that individuals who received mindfulness training showed smaller skin-conductance responses (typically larger in anxious individuals) when presented with negative emotional images (Ortner, Kilner, & Zelazo, 2007) and is consistent with evidence that individuals who received mindfulness training demonstrated less negative affect, measured by the Positive and Negative Affect Scale (Glück & Maercker, 2011; Jha, Stanley, & Baime, 2010; Chambers et al., 2008), had reduced emotional reactivity to stress (Britton, Shahar, Szepsenwol, & Jacobs, 2012) and that mindfulness training facilitated attention away from negative emotional faces and towards positive emotional faces on a visual probe task (Raedt et al., 2011).

In a study examining the effect of MBSR on cognitive measures of attention, Ekblad (2008) used the Computer Paced Auditory Serial Addition Task (PASAT-C) in which participants are sequentially presented with two digits and asked to enter the sum. After each trial, participants must ignore the sum, are shown a new digit, and are asked to calculate the sum of it and the previous digit (in a progressively shorter time span). At one-minute intervals participants rated their emotion. Results showed no effect on emotion rating, nor on attention. Due to observed effects of MBSR on attention control in other experimental paradigms (e.g. changes in executive attention, see earlier), it may be that the mindfulness intervention had low efficacy (e.g. 67% of individuals reported previous meditation experience).

Neurocognitive evidence for a relationship between mindfulness and emotion processing

Consistent with neurocognitive models of anxiety emphasizing reduced prefrontal inhibition of amygdalic threat-response, several studies have examined the functional neural architecture of emotion-processing control processes (for a review see Ochsner & Gross, 2005). An examination of negative elaborative thought processes (such as worry) found that individual differences in rumination correlated with increases in amygdala response during the evaluation of negative stimuli (Ray et al., 2005). This complements the notion that increased executive control (such as that observed after mindfulness interventions; e.g. Moore & Malinowski, 2010; Slagter et al., 2007; Chambers et al., 2007) could protect against/correct biased emotion-processing in anxious individuals. However, the relationship between dispositional mindfulness/mindfulness meditation and such emotion-control processes has only recently been investigated using neurocognitive measures, Modinos, Ormel and Aleman (2010) investigated the relationship between dispositional mindfulness (measured using the Kentucky Inventory of Mindfulness Skills; Baer et al., 2004) and fMRI readings elicited during appraisal and reappraisal of negative stimuli. Individuals high in mindfulness demonstrated greater activity in dlPFC, which was significantly correlated with reappraisal success, measured using a 4-point self-report scale for each trial. This supports the idea that individuals high in mindfulness are more able to focus on top-down goal-related cognitions, with reduced negative affect. However, no association between dispositional mindfulness and the reappraisal of negative stimuli was observed, providing no support for the notion that individuals with high levels of mindfulness are better able to engage in metacognitive insight.

Similarly, fMRI of emotional image appraisal found ‘mindful-attention training’ decreased amygdalic activity (associated with threat-processing) in response to positive images, and emotional images overall, in comparison to healthy controls (Desbordes et al., 2012). Participants undergoing 8-week MBSR courses have also shown increased left-sided anterior activation – an area associated with positive affect (Davidson et al., 2003), increased connectivity in areas associated with self-referential processes (Kilpatrick et al., 2011) and reduced cingulate and prefrontal activity during the appraisal of negative self-views (Goldin & Gross, 2010; Goldin, Ziv, Jazaieri, & Gross, 2012). Individuals with high levels of mindfulness also show increased prefrontal and reduced limbic activation during an emotion labelling task (Creswell, Way, Eisenberger, & Lieberman, 2007). This evidence is consistent with the notion that greater dispositional mindfulness may enable individuals to more efficiently allocate limited attentional resources towards negative emotional responses. However, the extent to which attentional control plays a functional role in the relationship between mindfulness and adaptive emotion regulation is currently unclear.

While this recent evidence demonstrates that mindfulness does have an effect on emotion control, future research should further examine the specific cognitive mechanisms affected. To the extent that initial findings suggest that mindfulness-based interventions can modulate attention control and adaptive processing of negative affect/stimuli, then mindfulness may become an effective method of targeting maladaptive biases in attention and threat processing in anxiety.

Summary and Conclusions

Anxiety focuses attention towards anticipated negative future events, at odds with the focus of mindfulness on objective interpretation of the present moment. Mindfulness therefore may affect anxiety through two mechanisms; by (1) allowing individuals to self-regulate their attention away from goal-irrelevant stimuli towards the present moment and current goals, and (2) reducing negative affect caused by emotional (threat) stimuli, and corresponding biases in threat appraisal, selective attention and interpretation of ambiguity that promote worry.

Recent investigations of dispositional mindfulness demonstrated it to be positively associated with measures of attention and emotion regulation, and studies of mindfulness-meditation have used a wide-range of interventions to examine their effects across self-report, behavioural and neurobiological measures of attention and anxiety. Several meta-analyses have also reported positive results for mindfulness-based anxiety treatments vs. active/wait-list controls (Chen et al., 2012; Vøllestad et al., 2012). However, there is still some debate as to the nature/operational definition of mindfulness itself (Brown & Ryan, 2004; Grossman & Van Dam, 2011; Grossman, 2011), and only recently has the field progressed to examining functional mechanisms of change.

Consistent with the view that different aspects of mindfulness (i.e. attention and awareness) may have differential implications for anxiety and mood disorder treatments (see Ruocco & Direkoglu, 2013), there is increasing evidence that mindfulness-based changes in attention functioning are highly relevant for reducing/correcting anxiety symptoms (Brown et al., 2011). Changes in executive attention may lead to better emotion regulation and reduced negative elaborative processing (i.e. worry) in anxious individuals, as well as reducing negative cognitive biases to anxiogenic threat-stimuli (Chiesa et al., 2013).

Taken together, the purported key role of attentional control in anxiety (Eysenck et al., 2007; Eysenck & Derakshan, 2011) and varied evidence that mindfulness impacts attentional functioning (Jha et al., 2007; Tang et al., 2012; see review in Tang et al., 2013) demonstrate a need for rigorous experimental testing of: i) the relationship between mindfulness and attention control (and by extension, anxiety), and ii) the extent to which this relationship affects individual differences in cognitive processes that characterise anxiety.

Summary of research aims.

The current thesis reports data from a series of studies in healthy volunteers that systematically examine the effects of mindfulness-meditation practice on attention and emotion-processing biases that characterise anxiety.

Study 1. The relationship between dispositional mindfulness, attentional control, worry and anxiety. Mindful individuals may be more adept at efficient and appropriate allocation of attentional resources towards goal-related cognitions (and reduced attention to unwanted negative thoughts). This cross-sectional survey study examines what are perceived as key elements of worrying rumination and attention control. Self-report measures will be used to determine if attention control and worry are components in the relationship between mindfulness and anxiety.

Study 2. The effect of open monitoring and focussed attention meditation on attention network function in healthy volunteers. This study extends evidence from self-report measures in study 1 to examine the effects of two aspects of mindfulness-meditation practice (FA and OM vs. non-intervention control) on objective measures of attention (using a modified attention network task).

Study 3. The effect of mindfulness on threat-appraisal and attention to threat in healthy volunteers. This study examines the effect of a more extensive/standard mindfulness intervention on threat appraisal (emotion-potentiated eye- blink startle) and selective attention/attention control (emotional variant of an eye-tracking antisaccade task).

Study 4. The effect of open monitoring and focussed attention practice on self-report, autonomic and neuropsychological response carbon-dioxide inhalation. The final study examines the acute effects of OM and FA practice in a novel experimental model of anxiety (inhalation of 7.5% carbon dioxide) that has been shown to mimic the subjective, autonomic and cognitive characteristics of trait anxiety and clinical GAD.

Chapter 2

Examining the relationship between mindfulness and trait anxiety: the role of attention control and worry

Introduction

Mindfulness and Attentional Control

Recent psychological models of anxiety (Attention Control Theory: Eysenck et al., 2007; Processing Efficiency Theory: Eysenck & Calvo, 1992) suggest that heightened states of anxious apprehension and persistent uncontrollable worry result from maladaptive attentional biases to anxiogenic threat-stimuli (see review by Bar-Haim et al., 2007). Mindfulness-based treatment programmes (e.g. MBSR and MBCT, see discussion in Chapter 1) have increased the use of 'mindfulness' in treating mood and anxiety disorders, and several studies have demonstrated its consistent clinical efficacy (see Coelho et al., 2007, for a review). Further clarification of the relationship between mindfulness and anxiety could help refine intervention effectiveness by identifying optimal pathways of change. In this chapter, I will examine the extent to which mindfulness may protect against dysfunctional negative elaborative cognitive thought processes in anxiety (i.e. worry) via improvements in attentional control.

While mindfulness originates from the Pali concept of *sati* ('awareness, attention and remembering'), recent debates regarding operational definitions highlight the need for accurate constructs to provide a theoretical basis for salient treatment methods. Recent conceptualizations of mindfulness have highlighted the role of attention and, to some extent, downplayed the role of acceptance, particularly in novice practitioners (Bishop et al., 2006; Brown, Ryan, Loverich, Biegel, & West, 2011; Brown & Ryan, 2003; Grossman & Van Dam, 2011). The Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003) is a measure of mindfulness that focuses on the presence/absence of attention to present occurrences, rather than other attributes associated with mindfulness. Recently, the relationship between attention and meditation studies has been demonstrated using self-report and behavioural measures (see Fan, McCandliss, Sommer, Raz, & Posner, 2002; Jha, Krompinger, & Baime, 2007; Tang & Posner, 2009). Mindfulness employs enhanced focus on the present moment, including internal cognitive processes (such as volitional attentional control). Increased mindfulness may therefore lead to positive effects on attentional control.

Two separate self-report studies (*N*s = 127, 132) found dispositional mindfulness to be positively associated with attentional control, and that the best predictor of mindfulness was low trait anxiety, which was partially mediated by attention control (Walsh et al., 2009). Eysenck, Payne and Santos (2006) suggest that anxiety focuses attention towards future events, at odds with mindfulness's focus on objective interpretation of the present moment. Increased dispositional mindfulness may cause increased attentional control, allowing anxious individuals to focus on present events rather than engage in uncontrollable negative elaborative thoughts (i.e. worry).

Influence of worry in generalized trait anxiety.

Recent conceptualizations of anxiety and mood disorders have stressed the importance of worry as a key component of anxiety responsible for decreased cognitive performance. Worry is a preoccupation with potential aversive consequences of current events (Borkovec, 1994). Attentional resource allocation towards worrisome thoughts reduces available resources for goal-directed mechanisms. Individuals' ability to regulate worry (i.e. regulate attention away from worrisome thoughts) is considered a factor behind observed cognitive dysfunctions in anxious individuals (Eysenck & Derakshan, 2011).

Increased mindfulness may therefore allow for better regulation of attentional resources, away from worrying thoughts, with a resulting reduction in anxiety. Previous studies have looked at the relationship between increased dispositional mindfulness and reductions in generalized anxiety disorder symptoms (Roemer et al., 2009) and a progression of this study found two mindfulness subfactors ('observe' and 'describe') to predict worrying tendencies (Fisak & Lehe, 2011). The role of attentional control and worry – that is, individuals' ability to focus limited attentional resources on goal-directed events rather than those that are stimulus-driven – is crucial to the relationship between mindfulness and anxiety.

Similar 'repeated negative thinking' (RNT) can be observed in the form of rumination, which places a similar demand on attentional resources but with different temporal orientation (i.e. past-focused rather than future focused; see Watkins, 2008). Both worry and rumination are unconstructive negative thoughts; that is, beyond adaptive anticipation to maladaptive reductions in goal-related behaviours. This study examines worry given its role as a defining feature in GAD (DSM-V: Andrews et al. 2010) and ii) that constructive goal-related attention is typically future-focused.

The current study measured levels of self-report dispositional/trait mindfulness, attention control, worry and generalized anxiety, and modelled relationships between these variables to test the hypothesis that individuals with higher levels of mindfulness will have increased attention control and reduced worry, with consequently reduced levels of generalized anxiety. This study will extend findings from Fisak and Lehe (2011), and is the first to examine functional mechanisms (i.e. attention control) and worry as mediators in the relationship between mindfulness and anxiety. Highly mindful individuals will be better able to maintain a present-moment focus, leading to reduced worrying. Therefore, it is hypothesized that attention control and worry will mediate the relationship between mindfulness and anxiety.

Method

Participants

26 male and 94 female participants were recruited through opportunity sampling ($M = 21.1$, $SD = 1.8$).[1] Participants were all undergraduate students or recent graduates from the University of Southampton. Participants took part voluntarily, were of varied ethnic background and spoke fluent English. Participants received course credit or £2 for participation. No participants withdrew during the study.

Measures

Participants provided informed consent before completing questionnaire measures of mindfulness, attention control, worry and anxiety (detailed below).

Mindfulness. The Mindfulness Attention Awareness Scale (MAAS; Brown & Ryan, 2003) is a 15-item instrument focusing on presence or absence of attention to current experiences (See Appendix B) e.g.“15: I do jobs or tasks automatically, without being aware of what I’m doing.” The MAAS was chosen to specifically measure awareness components of mindfulness. Respondents are asked to indicate how frequently they have

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[1]Correlational analysis on subsection of this data (from 49 participants) was performed for a document submitted as part of an MSc (Research Methods in Psychology) in 2009, before being extended for this study.

the described experience on a 6-point Likert scale from 1 (almost always) to 6 (almost never). The MAAS has been used frequently in previous studies, and has good internal consistency (α = .82 to .87) and correlates highly with other mindfulness measures such as the Five Factor Mindfulness Scale (Baer et al., 2008). Higher scores reflect greater mindfulness. In the current sample the MAAS had good internal reliability, *α* = .85, and group means were comparable (i.e. ± 2 standard deviations) with previous results in healthy student/young adult populations (Jermann et al., 2009; Walsh et al., 2009 Study 2)

Attentional Control. Attentional control was measured using the Attentional Control Scale (ACS; Derryberry & Reed, 2002), a 20-item scale examining individuals' ability to control attention in relation to positive and negative emotions, with items such as "8: I have a hard time concentrating when I am excited about something." (see Appendix C). Respondents indicate the frequency with which they experience the situation in the statement on a 4-point Likert scale ranging from 1 (almost never) to 4 (always). Good internal consistency between items is reported (α = .88). Higher scores indicate greater attentional control. The scale had good internal reliability in the current sample, *α* = .85, and group means were comparable to previous findings in healthy student populations (Reinholdt-Dunne et al., 2012; Walsh et al., 2009).

Worry. The Penn State Worry Questionnaire (PSWQ: see Appendix D) is a 16-item questionnaire used to assess participants tendency to worry, with items such as "1: My worries overwhelm me" and "8: I find it easy to dismiss worrisome thoughts," (Meyer, Miller, Metzger, & Borkovec, 1990). Participants are asked to rate the extent to which statements are typical of themselves from 1 (Not at all typical of me) to 5 (Very typical of me). Higher scores indicate greater tendency to worry. Studies have found internal consistency to be high in participants from both college and clinical populations (α = .91, Brown, Antony & Barlow, 1992), and high test-retest reliability (Molina & Borkovec, 1994). The scale had good internal reliability, α =.93 and group means were similar to those reported in healthy populations (Fisak & Lehe, 2011; Verkuil, Brosschot, & Thayer, 2007).

Anxiety. The Spielberger Trait Anxiety Inventory *(STAI-T*; Spielberger, Gorusch, Lushene, Vagg, & Jacobs, 1983) consists of a 4-point 20-item Likert scale assessing general disposition for anxiety, with items such as "31. I have disturbing thoughts" (see Appendix E). High scores reflect greater anxiety. The STAI-T is the most widely used measure of trait anxiety in clinical and non-clinical populations with high test-retest reliability and internal reliability, *α* = .86 (Barnes, Harp, & Jung, 2002), Respondents indicate their agreement with a statement such as "*10. I feel comfortable*" on a scale ranging from 1 (not at all) to 4 (very much so). The scale has high discriminant and convergent validity with other measures of anxiety and related constructs (Spielberger et al., 1983). The present sample had good internal reliability, $\alpha = .92$, with a trait anxiety sample mean comparable to other studies using the STAI in normal populations (Palma, Guimaraes, & Zuardi, 1994; Poma et al., 2005).

Results

Statistical Analysis

A cross-sectional design was used, and only questionnaires with no missing data were included in analysis. Visual analysis of Q-Q plots confirmed that all variables were normally distributed. Bivariate correlations examined relationships mindfulness, attention control, worry and anxiety. Multiple mediation analysis was calculated using 'PROCESS' regression-based path analytical framework for estimating direct and indirect effects in multiple mediator models (Hayes & Scharkow, 2013; Hayes, 2013). Model 6 was chosen according to recommendations by Hayes (2013) as it was consistent with predictions.

Mediation tests using a bootstrapping method (Preacher & Hayes, 2008) for relatively small sample sizes with 5000 samples. Direct effects of mindfulness on trait anxiety were calculated, alongside indirect effect of both mediators and each mediator individually (see Figure 2.1)[2]. Indirect effects were considered significant when bias-corrected confidence intervals did not include zero.

[2] Supplementary analyses examined the extent to which attention control mediated the relationship between mindfulness and worry without the inclusion of trait anxiety (see Appendix J).

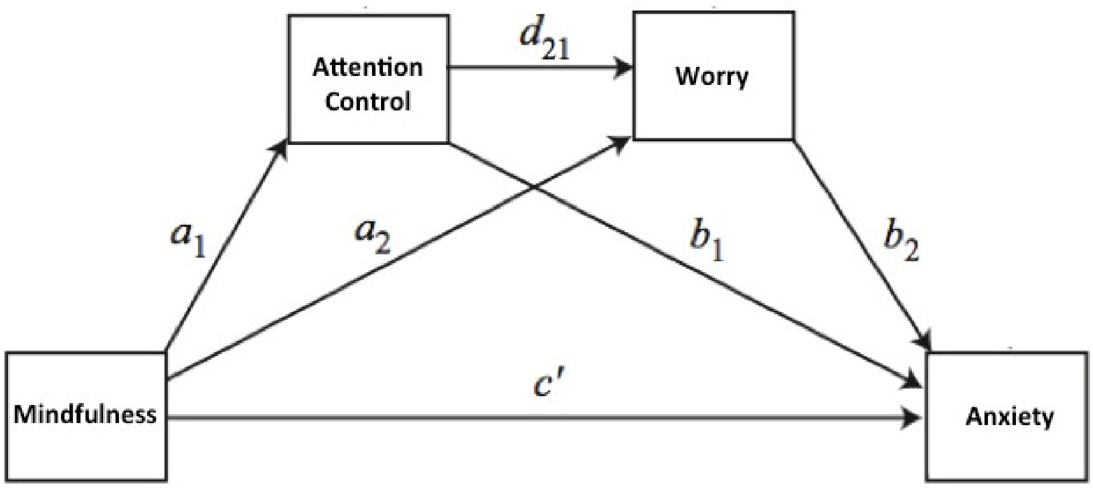

Figure 2.1 Template of analysis (Process Model 6, Hayes, 2013). Multiple mediation model of direct (c') and indirect (a_1b_1, $a_1d_{21}b_2$, a_2b_2) effects of mindfulness (MAAS scores: X) and trait anxiety (STAI scores: Y) mediated by attention control (ACS scores: M_1) and worrying tendencies (PSWQ scores; M_2).

Descriptive statistics are reported in Table 2.1. Bivariate correlations (Table ***2.1.***) revealed strong positive associations between mindfulness and attention control, and strong negative relationships between each of these variables, and worry and trait anxiety.

Multiple mediation analysis confirmed the total effect of mindfulness on anxiety was significant, [ß = -.32, *SE* = .08, 95% CI (-.47, -.16)] but the direct effect of mindfulness on anxiety (i.e. when accounting for effects of mediators: *c'*) was non-significant, [ß = -.13, *SE* = .07, 95% CI (-.28, .01)]. Mediation-models in which the association between mindfulness and anxiety was mediated solely by attention control (a_1b_1) and by attention control *and* worry ($a_1d_{21}b_2$) were both significant. A mediation model in which the relationship between mindfulness and anxiety was mediated solely by worry (a_2b_2) was not significant (see Table 2.1 for full summary of direct/indirect effects). Taken together these results indicate that the relationship between mindfulness and anxiety is mediated by attention control, and attention control and worry – but not by worry.

Table 2.1.

(A) Variable Means, Standard Deviations and Correlations (B) Direct effects (C) Indirect effects

A. Pearson's r correlations	Mean	SD	1	2	3	4
1. Mindfulness (MAAS)	55.4	11.0	-			
2. Attentional control (ACS)	47.3	7.3	.41***	-		
3. Worry (PSWQ)	49.2	12.9	-.31***	-.43***	-	
4. Trait anxiety (STAI-T)	41.7	9.9	-.37***	-.41***	.56***	-

B. Direct effects	ß	S.E.	95% CI
a_1: effect of mindfulness on attention control	.27	.05	(.16, .38)ˣ
a_2: effect of mindfulness on worry	-.15	.17	(-.37, .06)
d_{21}: effect of attention control on worry	-.69	.11	(-1.02, -.36)ˣ
b^1: effect of attention control on anxiety	-.24	.12	(-.48. -.00)
b_2: effect of worry on anxiety	.33	.06	(.21, .46)ˣ
c': effect of mindfulness on anxiety	-.13	.07	(-.28, .01)

C. Indirect effects		ß	S.E.	95% CI
a_1b_1:	mindfulness → attention control → anxiety	-.07	.05	(-.18, -.00)ˣ
a_2b_2:	mindfulness → worry → anxiety	-.05	.02	(-.13, .01)
$a_1d_{21}b_{2?}$:	mindfulness → attention control → worry → anxiety	-.06	.04	(-.13, -.03)ˣ

Note: (*) = p < 0.5, (**) = p < 0.01, (***) = p < .001. (ˣ) = bias-corrected confidence intervals do not include 0 (therefore significant effect)

Discussion

In line with hypotheses, mindfulness and trait anxiety were negatively correlated such that increased dispositional mindfulness was strongly associated with reduced levels of generalized trait anxiety. The current study is the first to show that attentional control and worry are mediating factors in this relationship. Specifically the overall model was significant but when accounting for the mediation of attention control and worry, the direct effect of mindfulness on anxiety was non-significant.

Although limited by their cross-sectional nature, these findings are consistent with suggestions that mindfulness increases objective focus on present events, as well as the notion that attention control may be a core mechanism through which mindfulness can reduce the worrisome thoughts that feature prominently in generalized anxiety (Fisak & von Lehe, 2012).

Currently, the driving force behind the expansion of mindfulness-related therapeutic programmes is the efficacy of treatments such as MBSR and MBCT in disorders involving emotional problems. However, the use of numerous different methodologies has resulted in a requirement for 'detangling' of the relationship between mindfulness and anxiety or depression. Walsh et al. (2009) found attentional control to constitute part of the relationship between dispositional mindfulness and anxiety, but observed that other factors were clearly implicated in the relationship. The finding of the current study, namely that individuals with increased attentional control are better able to focus on the present and reduce worrisome thoughts, further establishes this relationship. Moreover, it is directionally consistent with behavioural evidence that mindfulness-training can improve attentional subsystems (Jha et al., 2007; Slagter et al., 2007; Tang & Posner, 2009), and is related to reductions in anxiety (Vøllestad et al., 2012).

These results suggest that constructs of worry, attention control and anxiety are related, but functionally separate processes (correlational values of .31 - .56), consistent with the key role of worry in the Attentional Control Theory of anxiety (Eysenck et al., 2007): in which worry reduces available attentional resources for goal-directed functioning. That greater dispositional mindfulness is associated with fewer worrisome thoughts in individuals is important for understanding the noted effects of MBSR and MBCT on anxiety (Evans et al., 2008).

The study used the MAAS to maintain a stringent focus on specific cognitions of attentional control and worry. However, although the MAAS correlates well with other measures of mindfulness, it does not explicitly index facets of mindfulness that are accounted for in other scales such as attitude (Kentucky Inventory of Mindfulness Skills, Baer et al., 2004) and acceptance (Philadelphia Mindfulness Scale; Cardaciotto, Herbert, Forman, Moitra & Farrow, 2008). Further research may include these measures to further examine the relationship between aspects of mindfulness and attention control (as measured by self-report and objective performance measures) and anxiety.

Further research should also consider the similarities between worry and other RNTs such as rumination. Recent evidence has noted the conceptual similarities between such constructs and that many cognitive processes are common to both rumination and worry (McEvoy, Watson, Watkins and Nathan, 2013), and thus differences in attentional control associated with dispositional mindfulness may also inform mindfulness-based clinical interventions for sufferers of depression and anxiety sufferers with comorbid diagnoses. Initial cross-sectional examination of similar constructs include measures of rumination such as the Ruminative Response Scale (Treynor, Gonzales & Nolen-Hoeksoma, 2003).

In conclusion, this brief survey study has clarified the key role of attention control in how dispositional mindfulness is associated with reduced negative elaborative thought processes (i.e. maladaptive attentional allocation). Further research should extend beyond the limitations of a cross-sectional design, and these findings can be progressed by: i) examining how a targeted mindfulness-meditation based intervention can impact attentional functioning using objective (experimental) measures; and ii) determine whether correcting dysfunctional cognitions (such as maladaptive attentional biases) is a functional mechanism through which mindfulness impacts anxiety.

Chapter 3

The effect of focused attention and open monitoring meditation on attention network function in healthy volunteers.

Introduction

In the previous chapter, I established that attentional control mediates the relationship between mindfulness and anxiety (consistent with recent component-process models of mindfulness; see Holzel et al., 2011). It is possible that attentional control may be an important mechanism in how mindfulness protects against negative elaborative processing underlying anxiety (e.g. worry; Eysenck et al., 2007), and reduce maladaptive attentional biases (see review by Bar-Haim et al., 2007).

Though mindfulness/meditation-based interventions offer promise for a range of physical and neuropsychiatric conditions, a better understanding of the neuropsychological 'mechanisms of action' in meditation/mindfulness-based interventions is required to i) further optimise treatment protocols for clinical populations and ii) better inform a growing population of individuals who choose to incorporate regular practice into daily life (Halliwell, 2010; Holzel et al., 2011; Rubia, 2009). The following experiment builds upon the finding that attention control mediates the relationship between dispositional mindfulness and worry, by examining the effect of a guided meditation practice on an objective computerised measure of attention network function.

Neuro-cognitive models of meditation place specific emphasis on two distinct attentional processes; focused attention and open-monitoring (Lutz et al., 2008; Manna et al., 2010). Focused attention (FA) involves maintaining sustained selective attention towards a volitionally chosen object (e.g. localised sensation of breathing) and engaging in 'self-monitoring' for intrusive thoughts and attentional distractors. In contrast, open-monitoring (OM) involves no deliberate de-selection of stimuli, but active monitoring and acceptance of internal and external sensation to promote a receptive field of non-judgemental awareness. Hence OM attention mechanisms relate to both attentional and affective/attitudinal mindfulness facets, while FA exploits exclusively attentional skills (See Chapter 1 for discussion). As subcomponents of common mindfulness interventions used in clinical practice (Perlman et al., 2011), examination and potential differentiation of

FA and OM could be used to inform both specific clinical interventions and more general (non-clinical) mindfulness-meditation practices.

More general functional models of attention identify three core attention networks, namely: alerting, orienting and executive control (Fan et al., 2002). *Alerting* is the activation of an appropriately vigilant state. It is spatially broad and facilitates distributed processing of temporally anticipated, but not spatially localized events, and is synonymous with the sustained aspect of self-regulatory attention allocation models (Josefsson & Broberg, 2011). *Orienting* reflects the selection of, and direction of resources towards the spatial location of anticipated/salient stimuli. *Executive control* encompasses higher-level functions, including conflict resolution between competing stimuli and assimilation of sensory input to maintain appropriate attentional allocation (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick, Cohen, & Carter, 2004).

The attention network test (ANT) is a computerized reaction-time test that has been widely used to examine the performance/efficiency of the alerting, orienting and executive attention networks (Fan et al., 2002). It combines a cued reaction-time task and flanker task, and requires participants to make a speeded response to a central arrow (flanked by distracter stimuli) that is cued by a temporal-onset (alerting) and/or spatial location (orienting) visual stimulus.

Growing evidence from cognitive-behavioural paradigms suggests mindfulness meditation can modulate various aspects of cognition including attention stability during dichotic listening (Lutz et al., 2009), cognitive capacity in attentional blink paradigms (Slagter et al., 2007), and working memory (Chambers et al., 2007; van Vugt & Jha, 2011) - see Chiesa, Calati and Serretti (2011) for a recent systematic review of 23 studies. This work complements efforts in neuroimaging (Allen et al., 2012; Lutz et al., 2009) and mathematical modelling (Van Vugt & Jha, 2011) to clarify integrated neuro-psychological mechanisms in mindfulness meditation.

To date findings regarding the effects of mindfulness meditation/increased dispositional mindfulness on attention network function are mixed. Experienced meditators (compared to novices) can demonstrate increased orienting functioning (Van den Hurk et al., 2010) executive control (Jha et al., 2007; van den Hurk et al.) and alerting function after 1 month of intensive practice (Jha et al.). Similarly studies in naïve/novice participants have shown that 8-weeks of MBSR practice leads to improvement in orienting function (Jha et al. 2010), whilst short interventions comprising 5 x 20 minute sessions over one week improve executive attention (Tang et al., 2007) with two sessions shown to improve alerting function (Polak, 2009). Previous mixed results may reflect differences in the mindfulness-meditation practices used across studies (i.e. the extent to which they emphasize/combine FA, OM, acceptance, self-compassion etc.), and further argue the need to better understand the role of component meditation processes in modulating cognition and emotion processing (Lutz et al., 2008).

The present study directly compared the effects of focused attention and open monitoring meditation practice and subsequent in-session induction on attention network function as measured by the ANT. Healthy meditation-naïve participants were randomly assigned to three groups (FA, OM and control); they completed a modified ANT at baseline and following training. Research to date has predominantly examined the effects of mindfulness meditation on cognition, and only limited research has examined whether mindfulness modulates cognitive-affective mechanisms implicated in psychopathology e.g. selective processing of negative/threat stimuli (see Allen et al., 2012; Ortner, Kilner, & Zelazo, 2007). Therefore the ANT was modified to examine the effects of meditation on attention network responses to both non-word cues (used in conventional ANT paradigms) and also negative and neutral word cues that have been widely used in other studies of emotion processing in individuals with mood/anxiety disorder.

It was predicted that FA and OM mindfulness practice would increase executive control from baseline to follow-up compared to a relaxation control group (which would show no change). Further, it was predicted that greater improvement following focused attention given its emphasis on attentional acuity and efficient disengagement from distractor stimuli (such as flankers in the ANT). Furthermore consistent with cognitive models of threat processing it was predicted that the novel emotional ANT would reveal an effect of stimulus valence on orienting network function consistent with spatial hypervigilance to threat, and for this effect to increase following meditation (see Van den Hurk et al. 2010) and particularly after OM given its cultivation of greater receptive awareness to in-situ information.

Method

Participants

10 male and 66 female young adults (M = 20.3 years; SD = 4.1) with no prior formal experience of mindfulness meditation were recruited through advertisements placed around the University of Southampton. Participants received course credit or money in return for participation. Participants were randomly allocated to one of 3 experimental

groups: Focused Attention Meditation (N =24), Open Monitoring Meditation (N = 25), and test-retest control (N = 27). One-way ANOVA confirmed that groups did not differ significantly in age, $F_{(2, 73)}$, = .47, p = .63 or gender, χ^2 = 1.61, p = .45. Box-plots across the entire sample indicated that three participants in the control group were outliers on self-report generalized trait anxiety (STAI). To ensure groups did not significantly differ in baseline levels of trait anxiety these participants were subsequently removed from the study. Thus data is reported from 73 participants: FA group, n = 24, OM group, n = 25; control group, n = 24. Groups did not differ significantly in age, $F_{(2, 70)}$, = .40, p = .67 or gender, χ^2 = 1.45, p = .48.

Materials and Procedure

Participants attended pre- and post-intervention test sessions (see procedural diagram in Appendix L) during which they completed a modified attention network test (details below) and established standardized questionnaire measures of state and trait anxiety (STAI: Spielberger et al., 1983), attention control (ACS: Derryberry & Reed, 2002), worry (PSWQ: Meyer et al., 1990) and trait mindfulness (MAAS; Brown & Ryan, 2003). The study received approval from University of Southampton research ethics and research governance committees.

Self-report measures. Participants completed the following self-report measures described in Chapter 2: MAAS (α_{T1} = .84), ACS (α_{T1} = .79), STAI (α_{T1} = .91), PSWQ (α_{T1} = .94). All samples reported good internal reliability, and group means (Table 1) were comparable (i.e. within 2 standard deviations) with normal student population means in other studies following structured psychiatric and physical health screening (e.g. Fisak & Lehe, 2011; Poma et al., 2005; Walsh et al., 2009, see Chapter 2).

In addition, the Spielberger State Anxiety Inventory (SSAI; Spielberger et al., 1983) consists of a 4-point 20-item likert scale for assessing anxiety and nervousness in the present moment, with items such as “10. I feel comfortable” (see Appendix F) on a scale ranging from 1 (not at all) to 4 (very much so). The scale has high discriminant and convergent validity with other measures of anxiety and related constructs (Spielberger et al., 1983). The present sample had good internal reliability, α = .92, and the trait anxiety sample mean was comparable to other studies using the STAI in normal populations (Palma et al., 1994; Poma et al., 2005).

Emotional Attention Network Test (ANT). On each trial a central fixation cross was presented for 400 – 1600 ms followed by a cue (either a five letter negative word, e.g. 'FATAL', neutral word, e.g. 'FINAL', or non-word. e.g. 'XXXXX')[3] for 100 ms (except on no-cue trials). 400 ms after cue offset (or 500 ms in no-cue trials), one central arrow target and two pairs of flanker distractor arrows were displayed until the participant made a manual button-press response.

On double cue trials, the cue was displayed both above and below the fixation cross and alerted participants to the onset of the target (but not spatial location). On centre cue trials the cue was displayed in the location of the fixation cross and alerted participants to the onset of the target.

Reaction times from incorrect trials were removed from analyses. Alerting, orienting, and executive attention scores were calculated separately for each participant and cue-word-type condition (i.e. negative word, neutral word, non-word). Consistent with previous studies (Fan et al. 2002) the *alerting effect* was calculated by subtracting the mean RT from double-cue conditions from the mean RT on no-cue trials. The *orienting effect* was calculated by subtracting the mean RT on spatial-cue trials from the mean RT on centre cue trials (note both trial types provided information about target onset but spatial orienting was only cued on spatial-cue trials). The *executive control effect* was calculated by subtracting the mean RT of congruent trials, from the mean RT of incongruent trials such that large positive scores indicate poorer executive control (descriptive statistics, Table 3.2).

Meditation Training. Focused Attention and Open Monitoring meditation training groups were developed and led by a consultant psychiatrist (Dr Daniel Meron, DM) with clinical expertise in delivering mindfulness based interventions for inpatient and outpatient psychiatric services (since 2000) and several thousand hours of personal mindfulness

[3] Word lists were matched for length, first letter and last letter. Negative words: AGONY, ANGRY, BITCH, BLOOD,CHOKE, DEATH, DECAY, DREAD, DROWN, FATAL, HATED, KNIFE, NASTY, SCORN, SNEER, UPSET, VOMIT, WOUND, ULCER Neutral words: ALLOY, ABBEY, BRUSH. BREAD, CRANE, DOUGH, DAIRY, DINED, DOZEN, FINAL, HIRED, KNAVE, NAPPY, SPOON, STAIR, UNLIT, VALET, WORLD, UTTER.

practice (since 1990), rated as competence level 5/6[4] according to Crane et al. (2012). Each group attended 3 x 1 hour group training sessions across a period of 8 days. Each group session comprised an introduction, guided practice, reflective discussion and homework setting. Throughout the course participants were asked to complete 10 minutes of meditation practice each day prior to follow-up re-test. Practice was guided by a CD/MP3 prepared and recorded by DM (see Appendix O).

In the focused attention meditation, participants were asked to "*Find a place where the sensations of your breath are particularly clear right now…at the tip of the nose, the back of the throat, the chest or the abdomen"…. "Make a decision to stay with this place for the duration of this exercise rather than moving your awareness from one place to another."…"Turn your awareness towards this place…allowing your awareness to settle on this point…allowing the mind to become comfortable here"….."Maintain this focus, and if the mind wanders, gently return the mind to this place."…. "If you find your mind has wandered, lightly and firmly return your focus to this place…." "Really examining the sensation of the breath, and making the focus of attention as fine and as exact as possible – really pinpoint this one point where the breath is observed."*

In contrast, in the open monitoring meditation participants were asked to *"Allow a sense of awareness of the breath and physical sensations in the body generally to gradually expand"…."Allowing your focus to include the sounds that you're hearing, whatever the eyes see, and perhaps any smells to become within your field of awareness."…"Sitting here, with all of this, perhaps allowing your emotional tone, how you are feeling right now, to become part of this field of awareness – whatever sense of comfort or discomfort, any emotions you feel right now, allowing that to become part of your field of awareness right now, noticing any changes that may occur."*

All participants attended a follow-up test session approximately 20 days after the first test session [mean = 21.5; SD = 4.3 days], with no significant difference between groups in time between baseline and follow-up: $F(2, 70) < .41$, $p = .66$]. Immediately before completing the attention network task, participants completed their 10 minute

[4] Competency level 6 described as "Skill that the teacher has as a person is part of him/her as a person. While teaching, they are immersed in the process and no longer use rules, guidelines or maxims. She/he has deep tacit understanding of the teaching and is an original, flexible and fluid teacher. The breadth and depth of knowledge of the teacher at this development is an inspiration to others," (Crane et al., 2012).

guided meditation practice (to induce FA or OM) or were instructed to sit quietly and relax (control group).

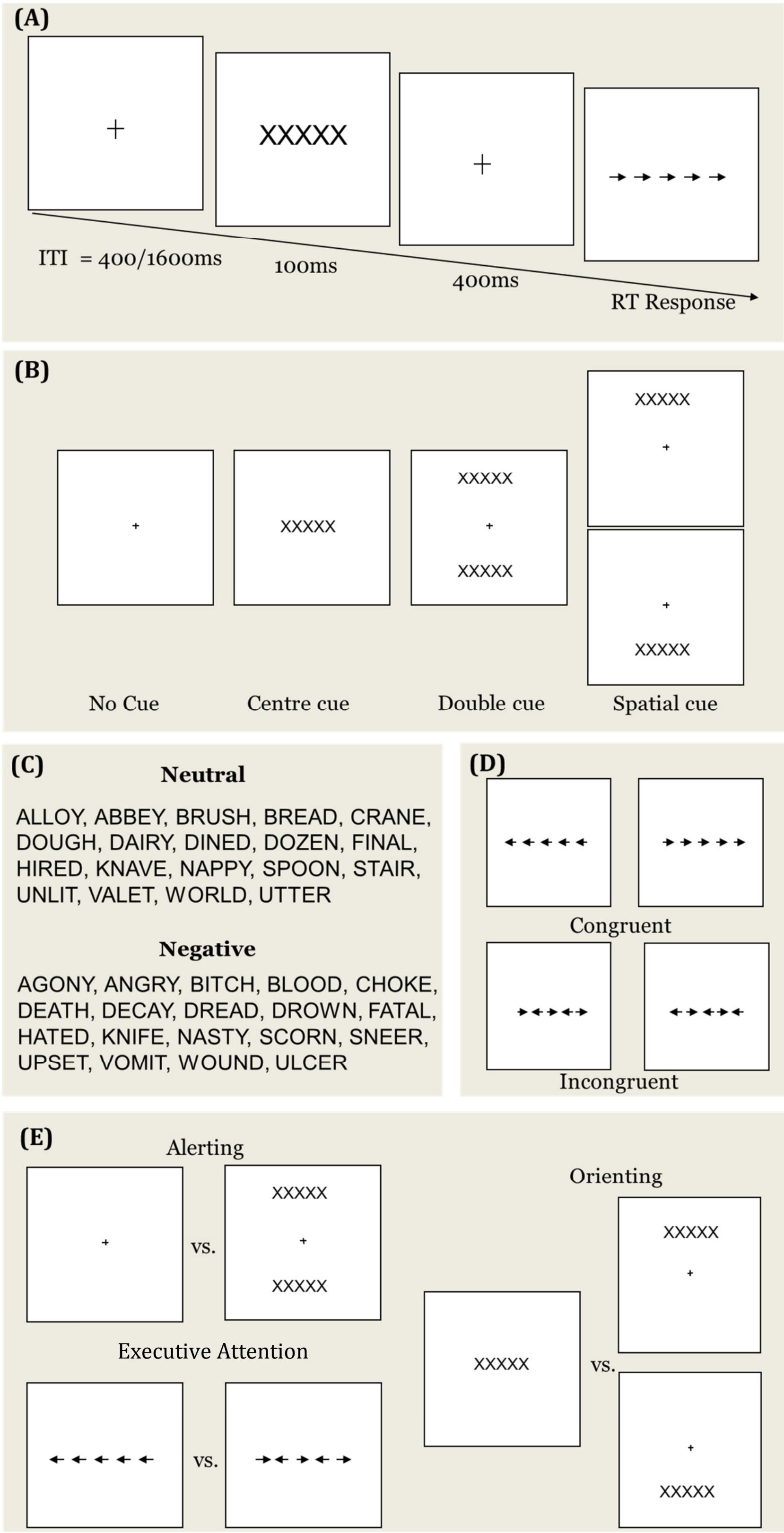

Figure 3.1. Summary of Attention Network Test trial types and cues. (A) Temporal sequence of presentation, (B) types of cue, (C) emotional cue word stimuli, (D) target stimuli, (E) comparisons by which attentional network function calculated.

Results

Group characteristics.

One way ANOVA confirmed that focused attention, open monitoring and control groups did not differ in baseline levels of self-report trait anxiety, attention control or dispositional mindfulness (

Table **3.1**).

Mixed design ANOVA with time as a within-subjects factor and group as a between-subjects factor confirmed that there were no significant effects of time, group or their interaction on self-report measures of mindfulness, anxiety, or attention control (see Table 3.1 for descriptive statistics). Thus FA and OM did not significantly alter state/trait anxiety and worry, nor perceived mindfulness and attention control.

Table 3.1 Self-report measures across groups for pre- and post- intervention test sessions.

	Focused Attention (n=24)		Open-monitoring (n=25)		No-intervention (n=24)	
	Pre	Post	Pre	Post	Pre	Post
Self-report measures						
MAAS	54.1	54.0	59.0	55.6	55.2	56.0
	(10.4)	*(9.9)*	*(10.1)*	*(12.0)*	*(11.5)*	*(9.8)*
STAI	40.1	40.3	42.2	39.9	44.7	43.6
	(8.5)	*(10.4)*	*(10.7)*	*(9.7)*	*(8.9)*	*(10.1)*
ACS	46.0	46.6	46.2	45.2	45.0	45.9
	(5.3)	*(5.6)*	*(8.0)*	*(9.5)*	*(7.7)*	*(7.9)*
PSWQ	46.6	42.8	48.8	47.7	43.6	42.8
	(11.5)	*(9.5)*	*(13.0)*	*(14.5)*	*(12.2)*	*(9.5)*
SSAI	35.0	33.9	35.2	33.2	38.3	37.2
	(8.1)	*(9.5)*	*(10.8)*	*(9.7)*	*(9.7)*	*(9.0)*

Effects of focused attention meditation and open monitoring meditation on attention network function.

Alerting, orienting and executive attention scores were each entered into separate mixed-design ANOVAs with group (FA, OM, Control) as a between-subjects factor and time (pre-, post- test) and cue-word-type (negative word, neutral word, non-word) as within-subject factors.

Analysis of executive attention scores revealed a significant main effect of time, $F_{(1, 70)} = 16.08$, $p < .001$, np^2 (partial eta squared)=.19, that was subsumed under a significant interaction between time and group, $F_{(2,70)} = 3.32$, p = .042, $np^2 = .087$ (see Figure 3.2; all other results from the ANOVA were non-significant, F's$_{(2,140)} < 2.28$; F's$_{(3, 70)} < 2.43$. Post-hoc paired comparisons revealed significant improvements in executive attention (i.e. reduced scores) at follow-up compared to pre-intervention baseline in both the focused attention and open monitoring groups $t_{(23)} = 3.57$, $p = .002$ and $t_{(24)} = 3.83$, $p = .001$ respectively, but no change in the control group, $t_{(23)} = 0.19$, $p = .85$.

Alerting attention network function was greater at follow-up compared to pre-test baseline, $F_{(1,70)} = 6.61$, $p = .01$, $np^2 = .03$] but was unaffected by group, cue-word-type and interactions between group, time and emotion, F's < 1.96. A corresponding analysis of orienting network function did not reveal significant results, F's$_{(2,140)} < 1.295$; F's$_{(4, 140)} < 1.90$; F's$_{(1, 70)} < 2.34$.

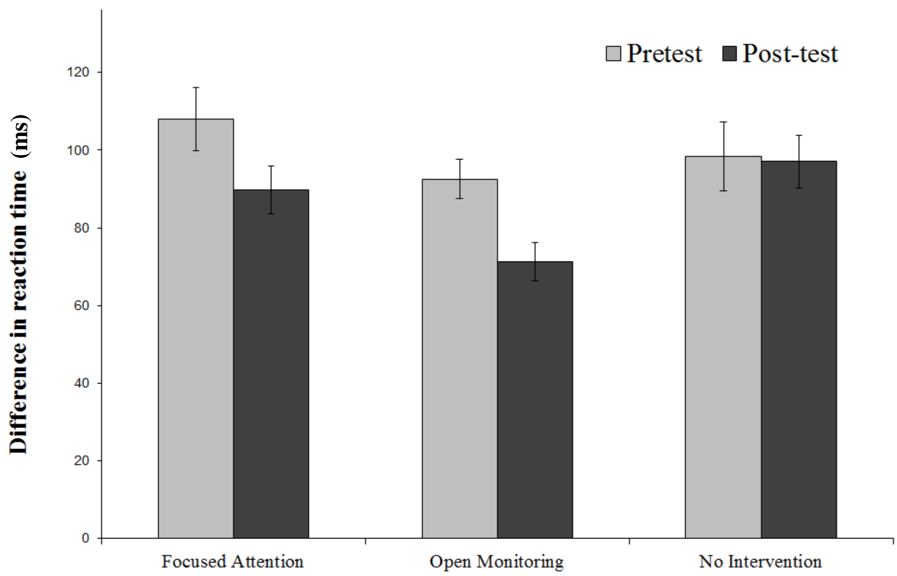

Figure 3.2. Executive attention control scores (collapsed across emotion conditions) in focused attention, open monitoring and no-intervention control groups at baseline (pretest) and follow-up (lower scores denote reduced distractor conflict/improved executive control).

Table 3.2 Mean ANT reaction times across groups for pre- and post- intervention test sessions.

			Focused Attention (n=24)		Open-monitoring (n=25)		No-intervention (n=24)	
			Pre	Post	Pre	Post	Pre	Post
Mean reaction times per cue-type *x* congruence *x* cue valence condition								
Central	Congruent	Negative	457.9	448.6	476.7	467.5	463.3	456.1
		Neutral	450.6	443.9	484.8	473.0	479.9	461.8
		XXXXX	456.0	444.1	484.7	469.0	471.5	459.8
	Incongruent	Negative	573.5	542.3	579.9	553.6	583.9	555.7
		Neutral	573.2	537.8	577.0	542.9	571.5	566.0
		XXXXX	571.6	540.5	587.7	544.1	588.6	563.8
Single	Congruent	Negative	448.3	427.1	473.0	448.8	457.0	444.8
		Neutral	440.4	431.7	464.0	441.5	458.9	439.2
		XXXXX	447.8	424.6	466.5	455.8	458.5	436.8
	Incongruent	Negative	540.2	515.2	546.3	512.2	551.8	526.8
		Neutral	534.7	496.6	555.4	510.7	550.4	525.1
		XXXXX	532.3	503.8	541.2	517.7	545.5	529.3
Double	Congruent	Negative	463.0	441.4	493.5	473.9	476.3	463.4
		Neutral	451.3	448.6	490.6	480.9	479.1	472.1
		XXXXX	462.4	443.4	496.4	473.7	490.6	46.1
	Incongruent	Negative	575.0	541.9	600.4	554.4	591.6	567.4
		Neutral	569.3	541.6	580.9	541.1	589.6	557.0
		XXXXX	580.5	541.7	583.8	549.5	594.3	573.9
No cue	Congruent		520.8	515.9	533.6	526.5	533.4	533.7
	Incongruent		610.6	575.6	605.7	595.5	617.0	601.2
Attention network function scores								
Executive Attention		Negative	106.5	94.1	94.5	76.6	103.5	95.8
		Neutral	111.6	83.9	94.6	66.4	93.2	92.0
		XXXXX	106.1	91.3	88.4	70.9	98.5	103.5
Orienting		Negative	21.5	24.3	18.6	30.1	20.3	21.1
		Neutral	24.3	26.7	21.7	31.9	19.7	32.3
		XXXXX	23.7	28.1	32.4	19.8	24.9	29.2
Alerting		Negative	46.7	54.1	22.7	46.8	46.1	52.1
		Neutral	55.4	50.7	29.4	50.0	46.5	54.7
		XXXXX	44.3	53.2	29.5	49.4	39.4	50.9

Notes: Self-report measures; Mindfulness Attention Awareness Scale (MAAS), Spielberger Trait Anxiety Inventory (STAI), Attention Control Scale (ACS), Spielberger State Anxiety Inventory (SSAI)..

Analysis of raw reaction times confirmed that participants were significantly quicker at follow-up compared to baseline, $F_{(1, 70)} = 13.94$, $p < .001$, however focused attention, open monitoring and control groups did not differ in the *extent* to which overall performance improved (Group x Time, $F < 1$). Separate analyses of error rates and RT-variability did not reveal significant effects of time, group nor their interaction, *F*'s < 1.

Associations between trait anxiety, mindfulness and attention network function.

Self-report mindfulness was positively correlated with self-report attention control at baseline; $r = .43$, $p < .001$, and both measures were negatively correlated with trait anxiety ($r_{mindfulness} = -.33$, $p = .005$; $r_{attention} = -.40$, $p = .001$) and worry ($r_{mindfulness} = -.33$, $p = .008$; $r_{attention} = -.49$, $p < .001$). Self- report mindfulness at baseline was further associated with greater executive attention as measured on the attention network task (i.e. reduced distractor interference), $r = -.25$, $p = .03$. All other results were non-significant.

For each measure, baseline and follow-up scores were highly correlated (consistent with levels of test-retest reliability reported in previous studies): mindfulness $r = .43$, $p < .001$; attention control $r = .40$, $p < .001$; worry $r = .88$, $p < .001$, trait anxiety $r = .66$, $p < .001$; executive attention $r = .63$, $p < .001$; and moderately correlated within alerting $r = .40$, $p <. 005$; and orienting $r = .25$, $p < .05$. The degree of change (baseline vs. follow-up) in self-report and attention network measures was not associated with minor variations in the amount of meditation practice (number of days) between baseline and follow-up, *r*'s < .13, *p*'s> .26.

Individual differences in *change* in attention network function (baseline vs. follow-up) did not covary with *change* in self-report mindfulness, attention control, worry, trait anxiety, nor state anxiety (*r*'s < .16). Thus the observed improvement in executive control in FA and OM groups occurred in the absence of and independent of any change in state/trait anxiety, worry, perceived mindfulness and attention control. Finally, baseline self-report measures of mindfulness, attention control and anxiety did not predict subsequent degree of change in attention network function (*r*'s < .22). Thus the effect of meditation training on executive attention was unaffected by prior anxiety severity and dispositional mindfulness.

Discussion

This study is the first to examine the effects of focused attention and open monitoring meditation on discrete human attention networks. Significant improvements in executive attention network function (but not alerting nor orienting function, nor global RTs, RT-variability or error rates) suggest that both FA and OM practice had a selective, rather than global effect on attention; specifically involving those mechanisms involved in the resolution of cognitive conflict between task relevant and task irrelevant/distractor stimuli. These results extend evidence that integrated mindfulness-based interventions can improve executive attention as measured by the ANT (Jha et al., 2007; Tang et al., 2007) and related behavioural paradigms (Josefsson & Broberg, 2011) and suggest FA and OM components as mechanisms through which mindfulness-meditation might elicit cognitive change.

Although there was no effect of meditation on change in self-report measures of anxiety and attention control, the observed changes in cognitive measures of attention may lead to subsequent improvements in anxiety/mood typically observed in more substantial mindfulness interventions. Notably, this experimental design could not definitively attribute attentional benefits entirely to short-term 'state' benefits of mindfulness meditation, and to determine the extent to which such benefits are representative of longer-term changes in dispositional mindfulness typically seen in experienced mediators (vs. novice control groups, e.g. Moore & Malinowski, 2009; Teper & Inzlicht, 2013). It remains to be seen whether even long-term clinical interventions (i.e. MBSR/MBCT) can reliably induce changes in dispositional mindfulness, and whether such changes are relevant to applications of mindfulness in clinical populations.

Positive correlations were observed at baseline between dispositional mindfulness and executive attention on the ANT, consistent with evidence of improved executive control in experienced compared to novice meditators (Jha et al., 2007). Thus both correlational and experimental studies provide convergent evidence that mindfulness-meditation can modulate executive attention.

OM and FA meditation produced similar increases in executive control. However given that FA meditation seeks to cultivate attentional acuity and efficient disengagement from distractor stimuli it was predicted that FA might lead to greater improvement in executive attention than OM. In OM practice (and in the group, homework and induction exercises) practitioners began each session by focusing attention before widening their field of awareness across modalities to monitor all internal and external sensory events. Indeed Lutz et al. (2008) note interactions and overlap between the development of FA and OM, particularly in naïve practitioners such as those recruited in the present study (see also Manna et al., 2010). Thus despite efforts to explicitly and functionally demarcate FA and OM practices, it is possible that some participants found it difficult to solely practice OM or FA, leading to similar improvement in executive attention. As such future studies should make additional comparisons between mindfulness component processes that more clearly differ in practice, content and function (e.g. FA/OM vs. change in self-perspective; see Holzel et al., 2011) and should use longer interventions to enable participants to develop mindfulness skills that they adopt routinely and without explicit direction. It may be that differentiation of FA/OM is challenging within the 'non-judgmental attention' context of mindfulness (such as that seen in MBCT/MBSR), and thus total demarcation would limit the ability of any findings to inform mindfulness interventions in clinical settings.

It is likely that the present findings reflect genuine effects of FA and OM on executive attention (rather than demand characteristics that might follow short-term practice and induction) as groups did not differ in broader measures of task engagement/effort (e.g. global reaction times, error rates, reaction-time variability) nor self-report measures of attention control and mood/anxiety.

Strong positive correlations between self-report measures of mindfulness and attention control, and negative associations with trait anxiety support findings from previous survey studies that associate anxiety, attention control and mindfulness (Walsh et al., 2009; Chapter 2). Furthermore, the findings described in Chapter 2 show that attention control fully mediates the relationship between mindfulness and anxiety, indicating that mindfulness meditation might alleviate anxiety in part though changes in attention control. Indeed a recent study of attention network (dys)function in anxiety highlights a specific deficit in executive control on the ANT in high trait anxious individuals (Pacheco-Unguetti et al., 2010), consistent with anxiety-related deficits in attention control observed in antisaccade paradigms (Derakshan, Ansari, et al., 2009; Garner et al., 2009) and predicted by Attentional Control Theory (Eysenck et al., 2007) – see Chapter 1. Given the impact of poor attention control on broader cognitive function and emotion processing in anxiety (e.g. exacerbating threat processing biases; Derryberry & Reed, 2002), future studies should clarify the extent to which meditation-induced changes in executive attention (early in the intervention as seen here) precede and promote subsequent improvement in emotion processing and self-report mood/cognition after further practice.

Contrary to predictions the results did not show any improvement in orienting in FA and OM groups. Increased orienting has been observed after 8 weeks of integrated MBSR (Jha et al., 2007) however shorter interventions appear not to modulate orienting (Polak, 2009, present findings). In this study orienting ANT scores had weak test-retest reliability ($r = .25$) compared to the executive attention index ($r = .63$) and it is possible that the extended emotional variant of the ANT was not optimized to detect differences in FA and OM on orienting over time (see Macleod et al., 2010 for related discussion). Furthermore there was no evidence of general spatial hypervigilance (orienting) to threat in the emotional variant of the ANT (i.e. negative cues were not more effective in directing spatial attention than neutral cues). These findings are consistent with null results often reported in low anxious groups using similar emotional cueing tasks (see the meta-analysis by Bar-Haim et al., 2007), and likely reflect the limited degree of 'threat' conveyed by these word stimuli in a healthy sample. Future studies should use stimuli from previously validated sets that control for arousal, emotional valence and presentation frequency, such as the International Affective Picture System (Lang, Bradley & Cuthbert, 2008: used in Finucane & Power, 2010) or the NimStim set of facial expressions (Tottenham et al., 2009: used in O'Toole, DeCicco, Hong & Dennis, 2011).

To conclude, this study shows that OM and FA meditation practice can improve executive attention. Furthermore evidence that dispositional mindfulness is associated with improved attention control (assessed by questionnaire and computerized-behavioural measures) and reduced anxiety, suggests OM and FA training might usefully target maladaptive deficits in executive attention that characterize certain mood and anxiety disorders. Further study should examine whether mindfulness-meditation can protect and correct threat-biases in emotion processing that are associated with dysfunctional executive attention (Eysenck et al., 2007).

Chapter 4

The effect of mindfulness practice on threat-appraisal and attention-to-threat.

Introduction

The previous chapter provides evidence that a short course of focused attention or open monitoring interventions can improve executive attention. These findings support previous research that suggest attention control may be a key mechanism through which mindfulness interventions might reduce anxiety (Jha et al., 2007; van den Hurk et al., 2010; Zeidan et al., 2010; Chapter 3). However the emotional modified version of the ANT did not reveal effects of FA/OM practice on emotion processing, and found no differential effects of FA and OM. Despite efforts to explicitly and functionally demarcate FA and OM practices, it is possible that some participants found it difficult to solely practice OM or FA leading to similar improvement in executive attention. The next study directly examines the effect of integrated mindfulness practice (with a practice/homework adherence check) on measures of threat appraisal and attentional bias that characterise anxiety.

Cognitive models of anxiety (Eysenck et al., 2007; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998) suggest that biased competition between bottom-up threat evaluation and top-down attention control systems promotes maladaptive cognitive biases; notably hypervigilance towards threatening stimuli, delayed disengagement from threatening stimuli, and a tendency to appraise/interpret emotionally-ambiguous stimuli as more threatening than non-anxious counterparts (Bishop, 2007). These maladaptive biases have been reliably and consistently demonstrated using a range of cognitive tasks, and occur at both early and late stages of threat-processing (see Bar-Haim et al., 2007, for a review). Study 2 used a novel, emotional variant of the Attention Network Test but did not reveal any effects of emotional word stimuli on attention network function, perhaps in part due to the mild emotional salience of these stimuli to low-anxious individuals. In study 3 I assess the effects of mindfulness practice on appraisal and attention to salient emotional pictorial stimuli.

Recent neurocognitive anxiety models suggest that dysfunction in amygdala-prefrontal circuitry promotes maladaptive threat-processing (Bishop, 2007). Models suggest that amygdalic hyperactivity coupled with hypoactivity in prefrontal regions increases sensitivity to threat (e.g. increases threat appraisal) and reduces attention control and emotion regulation (e.g. hypervigilance to threat), (see earlier discussion in Chapter 1).

Mindfulness and threat-appraisal in anxiety.

A low-level bias in stimulus-threat is central to neurocognitive models of anxiety, with several models explicitly highlighting this mechanism (e.g. Valence-Evaluation System in Mogg and Bradley, 1998; Threat-Evaluation System in Mathews and Mackintosh, 1998; Affective Decision Mechanism in Williams, Watts, MacLeod, & Mathews, 1988, see Chapter 1). Common to these models is the proposal that *stimulus-appraisal mechanisms* directly modulate attentional-allocation mechanisms at both early and late stages of information processing (see Cisler & Koster, 2011, for a summary). Evidence for a bias in threat appraisal in anxiety comes from studies that show that anxious individuals more readily interpret ambiguous homophones and sentences as negative than low anxious counterparts (Byrne & Eysenck, 1995; Eysenck, Mogg, May, Richards, & Mathews, 1991; MacLeod & Cohen, 1993), and evidence that such interpretive biases lead to increased elaborative thought processes (worry) and further cognitive dysfunction (see Eysenck et al., 2007).

Beyond 'interpretative bias' paradigms that are presumed to measure low-level and high-level processes, recent research has attempted to directly measure low-level threat-appraisal processes and used techniques that index amygdala threat appraisal specifically. A popular behavioural paradigm of threat appraisal (and that complements expensive imaging techniques) is the startle reflex paradigm: EMG-measurement of an eyeblink-reflex response to an auditory cue (e.g. 95 dB white noise for 50ms). The magnitude and latency of the startle reflex has been shown to be modulated by both stimulus characteristics (e.g threat value) and dispositional/personality attributes (e.g. level of anxiety (Grillon & Baas, 2003). For example, the magnitude of this reflexive response is potentiated by the presentation (typical duration ~3 seconds) of negative emotional picture stimuli (Cornwell, Mueller, Kaplan, Grillon, & Ernst, 2012; Garner, Clarke, Graystone, & Baldwin, 2011; Hamm, Greenwald, Bradley, & Lang, 1993; Vrana, Spence, & Lang, 1988) or the anticipation of threat (Dichter, Tomarken, & Baucom, 2002) compared to startle responses when presented with neutral images. Furthermore to the extent that startle amplitude and latency indicate amygdalic threat-appraisal, then individuals with presumed hypersensitivity in these neural mechanisms will show elevated startle fear-potentiated reactivity (e.g. anxious individuals: Antoniadis, Winslow, Davis, & Amaral, 2007; Bradley, Cuthbert, & Lang, 1990).

Previous evidence has demonstrated that attentional focusing can attenuate startle amplitude: goal-related focus towards a preceding visual image leads to reduced attention to the auditory cue (and a smaller startle amplitude; Anthony & Graham, 1985; King & Schaefer, 2010), and goal-driven focus towards the auditory cue reduces the effect of stimulus valence on conventional startle (Panayiotou, Van Oyen Witvliet, Robinson, & Vrana, 2012). ‘Prepulse inhibition’ (presentation of stimuli 150-300 ms prior to startle probe presentation) also attenuates startle amplitude regardless of stimuli valence (Bradley, Codispoti, & Lang, 2006; Levenston, Patrick, Bradley, & Lang, 2000), and is considered to result from greater resource allocation to the prepulse stimulus rather than the auditory startle probe.

Mindfulness-induced improvements in executive attention should allow individuals to better perform threat-processing cognitions. Through endorsing objective interpretation of stimuli (and more efficient/balanced allocation of attention resources), mindfulness may reduce prepulse inhibition in earlier stages of stimulus appraisal (i.e. help balance resources across stimulus modalities). This in turn may promote adaptive threat-processing in the later stages (i.e. reduce threat-potentiated startle magnitude). Participants who took part in a 15-minute mindful breathing exercise reported greater willingness to maintain contact with negative stimuli upon repeated exposure (Arch & Craske, 2006) indicating reduced threat-appraisal.

To date there is limited research into the effects of mindfulness/meditation on threat appraisal as indexed by the startle paradigm. Startle amplitudes *during* FA/OM meditation sessions were reduced compared to controls (case study: Levenson, Ekman, & Ricard, 2012), and startle amplitudes did not change after a mindfulness intervention (5-weeks) in comparison to a progressive relaxation therapy session (Delgado et al., 2010). King and Schaefer (2010) further report evidence that attentional control might affect emotional modulation of the startle reflex, while not affecting the initial (pre-pulse) response.

In this study I examine the effect of mindfulness practice on two components of threat appraisal in an emotional picture-potentiated startle reflex paradigm. While typical (3 second) stimulus presentation would allow for emotional appraisal of stimuli, shorter (200ms) stimulus presentation, consistent with the appraisal-independent attentional processes found in prepulse inhibition would reflect attentional resource allocation immediately preceding the startle probe. Examination of both stimulus presentation durations within the same task allows for examination of both short and long threat appraisal mechanisms within the same experimental paradigm. As mindfulness meditation is related to increased executive control (see findings from Chapter 3), more adaptive allocation of attentional resources would result in increased goal-related focus. Thus, mindfulness may reduce prepulse inhibition of startle responses by distractors (i.e. in 200ms presentations), and reduce fear-potentiated responses when more complete emotional appraisal of stimuli is possible (i.e. 3000 ms presentations).

The effect of mindfulness on attention to threat

Neurocognitive models of threat processing (in anxiety) suggest that threat-appraisal directly affects the subsequent allocation of attentional resources; (e.g. Goal Engagement System: Mogg & Bradley, 1998; Resource Allocation Mechanism: Williams et al., 1988; Attentional Control Theory: Eysenck et al., 2007 or resource competition: Mathews & Mackintosh, 1997).

Alongside biases in threat-appraisal, cognitive impairment in anxiety is also caused associated with misappropriation of limited attentional resources towards threat distractors (Eysenck & Calvo, 1992; Eysenck et al., 2007), and notably by hypervigilance or inhibited disengagement from threat (Bar-Haim et al., 2007).

Mindfulness-induced changes in the executive control of limited attentional resources should allow individuals to better perform such cognitive processes. Several computerized reaction time tasks have been used to probe these mechanisms (e.g. stop-signal, go no-go and Stroop paradigms – see Mobini & Grant, 2007, for a summary of these paradigms and their use). The antisaccade task (Hallett, 1977) is a comparatively simple eye-tracking task (not reliant on manual reaction times) that is sensitive to individual differences in attention control (see Ainsworth & Garner (2013) for a detailed review of its use in anxiety and mood disorders).

The antisaccade task requires participants to inhibit an automatic eye-movement (saccade) towards an abruptly-presented peripheral stimulus, and generate a volitional saccade in the opposite direction. This function, requiring inhibition, is compared with a ‘prosaccade’ task, in which participants generate a volitional saccade towards the peripheral stimulus. The antisaccade task provides two distinct performance measures that are well placed to reveal cognitive deficits that can be obscured in clinical/subclinical groups due to compensatory strategies/demand characteristics: i) *performance effectiveness* - proportion of trials in which participants are unsuccessful at making antisaccades (i.e.

error rate), and ii) *processing efficiency* - the time required to inhibit reflexive saccades and generate a volitional antisaccade, i.e. latency (Eysenck et al., 2007; Kristjánsson, Chen, & Nakayama, 2001).

Several studies have shown that high-anxious individuals are slower to make antisaccades than low-anxious counterparts (Ansari et al., 2008; Ansari & Derakshan, 2010; Derakshan et al., 2009), and make more errors under increased attentional load, such as processing negative emotional pictures (Garner et al., 2009) or angry facial expressions (Derakshan, Salt, & Koster, 2009; Reinholdt-Dunne et al., 2012). Further studies have found slower antisaccade latencies in clinical anxiety populations (Jazbec, McClure, Hardin, Pine, & Ernst, 2005) and when anxiety is induced through experimental conditions (Cornwell et al., 2012; Garner, Attwood, Baldwin, James, & Munafò, 2011).

Additionally, fMRI studies have found that successful suppression of reflexive saccades aligns with enhanced activity in dlPFC and vlPFC (Ettinger et al., 2008) and that fronto-parietal activity (measured by EEG/ERP) is reduced during poor antisaccade performance (Ansari & Derakshan, 2011).

Previous studies have not examined the effect of dispositional mindfulness or mindfulness meditation on attention (generally or to threat) in the antisaccade paradigm. However previous studies have reported better inhibition of distractor stimuli in those individuals who report higher levels of mindfulness (Lee & Chao, 2012), and that mindfulness can predict executive functioning (study 2 of present thesis; Oberle, Schonert-Reichl, Lawlor, & Thomson, 2011). In this study I examine the effect of mindfulness training on antisaccade performance, and assess the extent to which mindfulness induced changes in threat appraisal (measured by startle) covary with predicted change in attention to threat distractors in an antisaccade task.

In the previous chapter the mindfulness interventions had no effect on robust self-report measures of mindfulness, state/trait anxiety, worry or attentional control.. This may be due to limited homework practice amongst participants. To address this, this study will adopt a 1-month intervention with online monitoring of practice habits, alongside novel in-session measures of autonomic arousal typically associated with anxiety (heart-rate variability; see Dishman et al., 2000; Friedman & Thayer, 1998; Gorman & Sloan, 2000).

Hypotheses

It is predicted that increased mindfulness (induced through practice, and in individuals with higher dispositional levels at pre-intervention) will:

i) improve threat-appraisal (reduced fear-potentiated startle responses in 3000ms condition; increased startle amplitudes in 200ms condition))
ii) increase inhibitory functioning (better antisaccade performance)
iii) improve attention-to-threat (better antisaccade performance for emotional stimuli).

Method

Participants

65 participants (44 female) were recruited through the University of Southampton undergraduate participation scheme. Participants had a mean age of 20.2 years (*SD* = 2.8) and received course credits in return for participation. Participants were randomly assigned to one of two groups: a mindfulness intervention, *N* = 19, *M* = 19.8 (*SD* = 1.5), and a test-retest control group, *N* = 20, *M* = 20.5 years (*SD* = 3.6). Groups did not significantly differ in age, $t_{(64)}$ = .-.97, *p* = .33, nor gender, χ^2 = .35, *p* = .56.

Design

The study used repeated-measures to examine the effect of 1-month of mindfulness training on self-report measures, startle reactivity (threat appraisal) and antisaccade performance (attention to threat distractors), relative to an inactive test-retest control group (see procedural diagram, Appendix M).

Self-report measures.

Participants completed the following self-report measures: STAI-T/S, PSWQ, ACS, MAAS. Group means were comparable to existing findings with healthy student populations (see Chapter 2 for details, Appendix B-F).

Alongside the MAAS, participants completed the Kentucky Inventory of Mindfulness Skills (KIMS; Baer et al., 2004). The KIMS is a similar 39-item 5-point likert scale inventory that assesses 4 mindfulness skills: *observing* various internal (e.g. cognitions, bodily sensations) and external (e.g. sounds, smells) stimuli, *describing* observed stimuli, *acting with awareness* according to such observed stimuli and *accepting without judgement* observations that have been made (see Appendix G). KIMS has good internal consistency (α = .91 to .76 across subscales) and good test-retest reliability (r = .86 to .65 across subscales). Higher scores indicate increased mindfulness skills. Group means in the present sample were comparable to published findings using healthy student sample groups (Moore & Malinowski, 2009).

The psychometric properties of each measure in the current sample were as follows: STAI, α_{T1} = .89, α_{T2} = .92, SSAI, α_{T1} = .92, α_{T2} = .92, PSWQ, α_{T1} = .94, α_{T2} = .94, ACS α_{T1} = .84, α_{T2} = .86, MAAS α_{T1} = .83, α_{T2} = .87, KIMS α_{T1} = .72, α_{T2} = .77.

Participants also complete basic visual analogue scales (VAS, see Appendix K) of mood and anxiety (McCormack, De L. Horne, & Sheather, 1988). Each scale consisted of a 150 mm horizontal dotted line, in which participants were instructed to mark the scale according to the extent they felt a specific mood, from 0 (Not at all) to 150 (Extremely). Scales were given for anxiety (VAS-Anx), happiness (VAS-Happ) and attentiveness (VAS-att). Previous work on attention-training has used similar scales (Heeren, Lievens, & Philippot, 2011; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002)

Pictures used in Startle and Antisaccade Tasks (International Affective Picture System).

8 negative and 8 neutral colour images were selected from the International Affective Picture System (Lang, Bradley & Cuthbert, 1997) using normative valence ratings (Scale = -4 to +4, $M_{neutral}$ = 1.2, $M_{negative}$ = -3.1) and arousal ratings (Scale = 0-8, $M_{neutral}$ = 2.9, $M_{negative}$ = 5.8). For non-emotional practice trials a yellow square was used. Emotional stimuli were presented on a computer screen (8 x 5.5 visual degrees), viewed at at 60cm, and displayed 4 times in 2 blocks of 64 trials (balanced for trial type and location). Stimuli were presented using Inquisit 3 software (Millisecond Software, Seattle, WA).

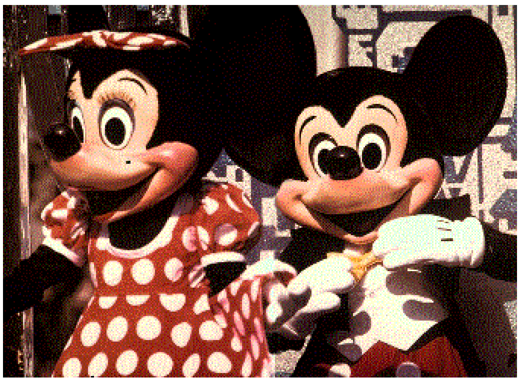


Figure 4.1 Examples of emotional stimuli used: negative (right hand image) and neutral (left hand image).

Startle Probe

Each experimental trial began with a central fixation cross presented for 1000ms, which participants are instructed to look towards. A visual stimulus was then presented for 4000ms. During picture presentation participants received an auditory startle probe (96 dB for 50 ms with near instantaneous rise-time) either 3000 ms or 200 ms after picture onset. Picture offset was followed by an ITI of 11s (total trial length = 16s). Figure 4.2 demonstrates this sequence presentation.

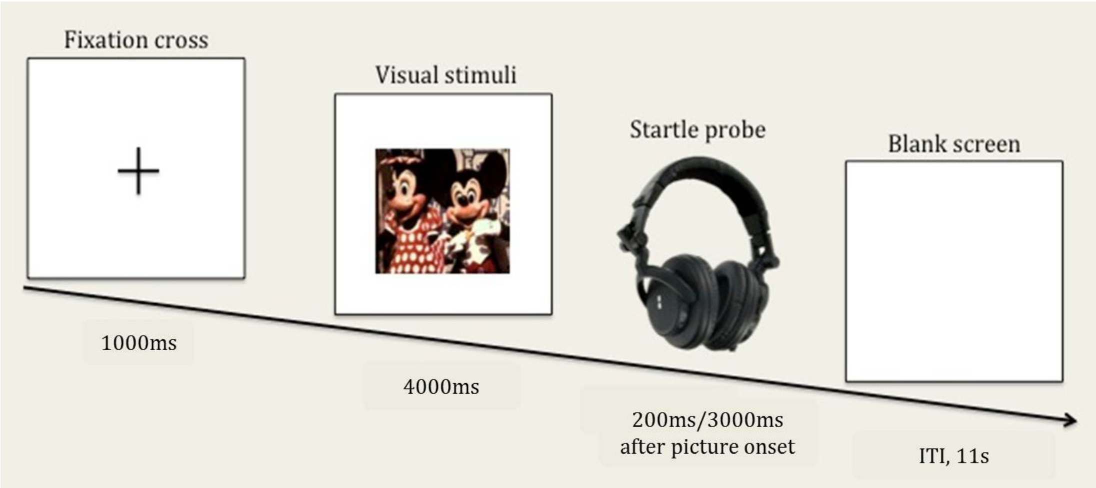

Figure 4.2. Trial events in a startle probe (experimental trial).

Baseline physiological measures were recorded during a 1 minute baseline. (serving to both accustom participants to the equipment as well as allow confirmation of satisfactory data acquisition). Participants were familiarized to the startle probe using three acoustic probes, presented 20 seconds apart and in the absence of pictures. Responses to these familiarization startle probes were discarded from analysis.

Antisaccade Task.

Trial events in antisaccade task (see Figure 4.3)**.** Each trial began with a cue indicating whether the trial was prosaccade (look towards the picture, indicated by 'TOWARDS') or antisaccade (look at the opposite side of the screen to the picture, indicated by 'AWAY') presented centrally for 2000 ms. This was followed by a blank screen for 200 ms before the emotional stimulus was presented on either the left or the right hand side of the screen for 600ms. After a 50 ms inter-stimulus interval (ISI) an arrow was presented on either the left or right side of the screen. To increase task-demand on each trial, participants were asked to classify the direction of the arrow by pressing the corresponding button on the labelled keyboard. The mean intertrial interval was 1000ms, ranging from 750 – 1250ms.

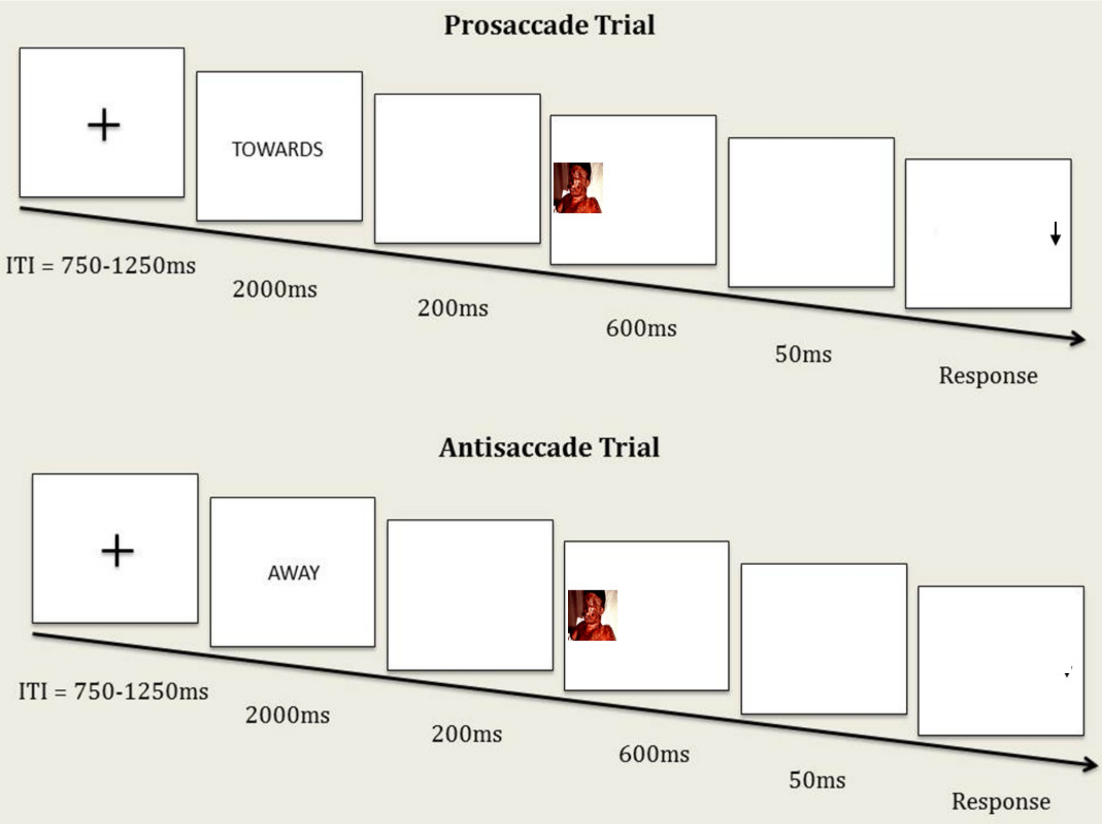

Figure 4.3. Trial events in the antisaccade task (not to scale).

Participants completed one block of 16 practice trials before being given an opportunity to ask questions. They then completed two experimental blocks of 64 trials separated by a short break. Trials in each experimental block consisted of 32 antisaccade trials (16 negative, 16 neutral stimuli described above) and 32 prosaccade trials (16 negative, 16 neutral).Trials were counterbalanced for stimuli location, probe location and probe type (up/down).

Psychophysiological Data Collection.

Horizontal eye movements (antisaccade task) were measured using electo-oculography – two 8 mm pinch electrodes placed 1cm from the outer corner of each eye. Eye blink startle response was measured electro-myographically from the orbicularis oculi, using two 4 mm electrodes placed approximately 0.8 cm below the pupil and outer canthus of the left eye. Electrodes were sampled at 1000Hz, using an MP150-amplifier and AcqKnowledge 3.8.1 software (Biopac-systems, Goleta, CA). Heart-rate variability was also recorded using electrocardiography taken from twin electrodes attached to both wrists (Acqknowledge). HRV outputs included the average standard deviation of peak-to-peak beat intervals (SDNN), mean heart-rate during HRV data recordings, and sympathetic-vagal system activation ratio.

Procedure

Participants were asked to read and sign an information sheet and consent form in which they were informed that they could withdraw from the study at any point, and were given the opportunity to ask questions regarding the procedure.

Once the consent form was signed and participants were satisfied they understood the experiment, state self-report measures were completed and participants were then sat in a low-lit room 60 cm from the computer screen and physiological electrodes were attached. Onscreen instructions, explaining how to complete computer tasks, were presented onscreen and verbally to participants, and they were given an opportunity to ask questions before the task began. After completing the computer tasks, physiological electrodes were removed and participants completed the remaining self-report measures. At the end of the session participants were randomly assigned to an intervention/control group.

Intervention

Group intervention sessions took place in a spacious room in the University of Southampton, led by a NHS Consultant Psychiatrist who was an experienced mindfulness practitioner (1000+ hours, since 1990, rated as Level 5/6 according to Crane et al., 2012) and expert in delivering mindfulness-based interventions (since 2000). Each intervention session lasted approximately 45 minutes and involved a brief description of one or two exercises followed by formal instructor-guided practice. The intervention comprised both FA and OM practice from study 2 (see below).

Sessions typically began using FA-based practices, such as *"Find a place where the sensations of your breath are particularly clear right now....at the tip of the nose, the back of the throat, the chest or the abdomen"*, and *"Turn your awareness towards this place… allowing your awareness to settle on this point… allowing the mind to become comfortable here."* After 10-15 minutes of this practice, instructions began to incorporate OM-aspects, such as *"Allow a sense of awareness of the breath and physical sensations in the body generally to gradually expand" and "Allowing your focus to include the sounds that you're hearing, whatever the eyes see, and perhaps any smells to become within your* *field of awareness,"* lasting a further 10-15 minutes. Sessions ended with a group discussion about practices in which participants were encouraged to voice opinions and queries about the practices.

After this, groups were given the opportunity to discuss and ask questions about the session. The intervention group had a weekly group intervention session, in groups of 15-20, supplemented by a daily 15-minute homework practice. All participants in the intervention group attended all practice sessions. Participants were not made aware of any conceptual differences between 'meditation' and 'mindfulness', and the skills practiced were referred to as 'meditation' and 'relaxation'. The control group was 'inactive' and did not attend any training sessions in between the pre- and post-intervention sessions.

Mindfulness Homework Sessions

The homework practice, accessible online via a purpose-built website, consisted of a recorded .mp3 practice by the teacher (for details see Appendix O), during which participants were asked twice (at 5-minute intervals) to click the mouse button to confirm their attendance at the computer. Participants' homework completion rate (completed practices/days between test sessions) was recorded automatically allowing for an accurate determination of individuals' homework participation.

Post-intervention Test Session

At post-test, all participants completed the same measures in the same order as in the pre-test session. There were no between-group differences in the number of days between pre-test and post-test sessions ($M_{mindfulness} = 35.5$, $M_{control} = 31.1$, $t_{(54)} = 1.64$, $p = .11$). Participants in the experimental groups were asked to complete the 15-minute homework practice session before completing the behavioural tasks and self-report measures. Control participants were asked to 'sit quietly and relax' during this time but were given no specific instructions on relaxation.

Startle probe pre-analysis

Consistent with previous studies startle amplitude was defined as the difference in amplitude between the mean EMG in the 50 ms prior to the startle response, and the maximum EMG response between 20 ms and 250 ms after probe presentation. Prior to analysis, startle latencies and amplitudes were checked for abnormalities using histograms, and 4 participants were excluded as extreme outliers (1 from control group, 3 from mindfulness group). As in the previous experiment, the social desirability scale (SDS) was administered in both sessions to assess ‘self-presentation bias’, with scores above 8 set as exclusion criteria on the grounds of demand characteristics. No participants recorded scores greater than 8.

Heart-rate variability was filtered using a 0.5 – 30Hz band-pass filter and correlated with example R-R waveforms to eliminate noise, according to procedures laid out in previous literature (Berntson et al., 1997; Hejjel & Kellenyi, 2005). Comparisons of variability were made using the average standard deviation of peak-to-peak durations (SDNN), mean HR during the monitoring period, and sympathovagal balance (Cohen, Matar, Keplan & Kotler, 1999). These measures were not analyzed for the antisaccade task due to the presence of artifacts produced by the manual button press response.

Antisaccade task pre-analysis

Saccade direction and latency were scored manually by a researcher who was blind to trial type (anti vs. prosaccade) and participant group (mindfulness vs. control) using AcqKnowledge 3.8.1. Saccades judged to be indicative of anticipatory eye-movements (occurring within 100 ms of stimulus presentation) and saccades that did not terminate in either stimulus or opposite-stimulus location (scored as subtending less than 6° visual angle) were removed from analysis, alongside scores from any participants who did not complete the experimental protocol.

According to visual analysis of error-rate histograms, 5 participants were judged to have an error rate in excess of that considered usual for the antisaccade task, in line with Garner et al., 2011, (i.e. likely due to misinterpretation of task instructions, or adoption of an erroneous task-strategy) and were excluded for further analysis. Distributions of antisaccade error-rates and latencies were examined and met assumptions of normality using Shapiro-Wilk’s test, *p’s* > .05.

Results

Group characteristics

Shapiro-Wilks tests confirmed that self-report measures at Time 1 in both the intervention and the control group did not deviate from normality; *p*’s > .05. Chi-square tests found that groups did not differ significantly in gender, $\chi^2 = 0.23$, $p = .58$, and an independent samples t-test found no significant differences in age, $t_{(39)} = .64$, $p = .43$. Participants receiving mindfulness training completed homework practice on an average of 27.2 days (*SD* = 10.1).

Self-report data from the questionnaires at Time 1 and Time 2 is presented in Table 4.1. An independent-samples t-test of dispositional and state/current scores found no significant differences between groups across all self-report measures, and groups were considered appropriately matched at T1.

Bivariate correlations examined associations between dispositional trait self-report scores. Associations between STAI, PSWQ, ACS and MAAS were consistent with those observed in Chapter 2 (*r*s > -.21, *p*s < .05). Greater KIMS scores were associated with decreased anxiety, $r = -.47$, $p = .001$, increased attention control, $r = .57$, $p < .001$, decreased worry, $r = -.35$, $p = .02$ and decreased mindfulness measured with the MAAS, $p = .56$, $r < .001$.

Further analysis of associations between *changes* in self-report measures (from T1 to T2) found a significant relationship between increases in anxiety (STAI) and decreases in attention control, $r = -.31$, $p = .04$ and mindfulness (KIMS), $r = -.40$, $p = .006$. Increases in worry were also related to increases in anxiety, $r = .58$, $p < .001$ and decreases in mindfulness (KIMS), $r = -.38$, $p = .01$.

Does mindfulness training affect self-report measures of anxiety?

Self-report data was entered into a 2 (time: T1 vs T2) x 2 (group: mindfulness vs. control) mixed-design ANOVAs. There were no main effects of time, *F*s < 2.00, *p*s > .16, or interactions between time and group, *F*s < 1.92, *p*s > .17 on any self-report measures of anxiety. Related analysis of state measures suggested no differences between groups in self-report data at Time 1, *t*s < 1.7, *p*s > .10. There was a main effect of time on visual analogue scale measures of anxiety, $F_{(1,38)} = 4.10$, $p = .05$, with participants reporting less anxiety at Time 2 (*M* = 37.9) than Time 1 (*M* = 46.8). Participants also decreased in attentiveness from Time 1 (*M* = 96.9) to Time 2 (*M* = 87.2), $F_{(1,38)} = 5.51$, $p = .03$.

Table 4.1

State and trait group characteristics at T1 and T2.

	Mindfulness (N=19)		Control (N=20)	
Trait self-report measures				
	T1	T2	T1	T2
STAI	40.7 (9.5)	40.2 (10.1)	41.8 (8.9)	43.4 (10.5)
ACS	48.5 (8.7)	49.6 (7.8)	46.3 (7.3)	47.1 (8.2)
PSWQ	46.9 (13.0)	45.1 (12.2)	45.2 (13.4)	44.1 (12.2)
MAAS	54.1 (11.9)	55.9 (13.3)	54.6 (12.3)	55.3 (13.1)
KIMS-total	116.7 (12.3)	119.1 (16.8)	114.8 (14.0)	116.9 (12.2)
KIMS-O	33.4 (5.2)	33.2 (6.5)	32.5 (5.9)	32.1 (6.8)
KIMS-D	25.6 (6.6)	27.1 (7.9)	24.0 (5.2)	25.5 (5.9)
KIMS-AA	30.2 (4.1)	31.5 (5.8)	29.7 (3.9)	29.9 (4.1)
KIMS-AJ	27.6 (5.8)	27.6 (7.7)	28.6 (6.3)	29.5 (7.5)
State self-report measures				
SSAI	34.9 (8.0)	34.6 (8.0)	38.1 (11.0)	38.0 (9.7)
VAS-Anx	40.8 (20.3)	31.5 (19.4)	52.8 (30.3)	44.4 (31.7)
VAS-Att	99.5 (16.9)	90.9 (26.3)	96.4 (20.9)	83.0 (19.7)
VAS-Happ	82.2 (27.3)	80.2 (27.0)	85.2 (23.9)	74.1 (26.7)

Note: STAI-T = State-Trait Anxiety Inventory, ACS = Attention Control Scale, PSWQ = Penn State Worry Questionnaire, CFQ = Cognitive Failures Questionnaire, MAAS = Mindful Attention Awareness Scale, KIMS = Kentucky Inventory of Mindfulness Skills (O = observing, D = describing, AA = acting without awareness, AJ = accepting without judgement), FFMQ = Five-Facet Mindfulness Questionnaire, O = observing, D = describing, A = acting with awareness, NJ = non-judgemental attitude, NR = being non-responsive to internal moods). *all t-values were non-insignificant, p's > .3.

Does mindfulness training affect autonomic measures of anxiety?

Independent t-tests showed that participants in the control group had a significantly higher baseline heart-rate than individuals in the mindfulness group, $t_{(40)} = -4.16$, $p < .001$, although groups did not differ on SDNN and sympathovagal balance, Heart-rate variability scores during the startle task (SDNN, sympathovagal balance) and mean HR during task were examined using a 2 (time: pretest vs. posttest) x 2 (group: intervention vs. control) ANOVA. No interactions were observed involving group across all measure, *F*s < 2.7, *p*s > .11. There was a main effect of time on SDNN, with reductions in SDNN in both groups from T1 to T2, $F_{(1,42)} = 12.96$, $p = .001$. Sympathovagal balance ratio did not change over time, $F_{(1,42)} = 2.45$, $p = .12$, and mean HR did not differ from T1 to T2, $F_{(1,42)} = 1.00$, $p = .32$.

Table 4.2. Autonomic measures of anxiety in mindfulness and control groups.

	Mindfulness (*N*=19)		Control (*N*=20)	
	T1	T2	T1	T2
Mean HR	74.9 (9.2)	75.9 (6.5)	87.0 (11.2)	82.7 (9.7)
SDNN	.13 (.07)	.09 (.04)	.10 (.05)	.08 (.04)
SV balance	1.40 (.55)	1.48 (.72)	1.67 (1.0)	2.71 (1.0)

Note: T1 = Time 1, T2 = Time 2, Mean HR = mean heart-rate as measured during the startle task, SDNN = standard deviation of beat-to-beat intervals, SV balance = sympathovagal balance.

Does mindfulness training affect startle reactivity (threat appraisal)?

Startle amplitudes and latencies used to calculate fear-potentiation (calculated as the difference between response amplitudes in negative and neutral conditions) are presented in Table 4.3. There were no differences in baseline amplitude or latency scores in 3000 ms trials, *t*s <-,52, *p*s > .61. There was a trend towards a baseline difference in 200ms latencies, $t_{(43)} = -1.99$, $p = .06$, but amplitudes were similar across group, $t_{(43)} = -.52$, $p = .18$.

Separate analyses were conducted for each stimulus duration, as 3000 ms and 200 ms presentations were hypothesized to examine different threat-processing mechanisms. Startle amplitudes and latencies for 3000ms trials were examined in separate 2 (time: T1 vs. T2) x 2 (emotion: negative vs. neutral) x 2 (group: mindfulness vs. control) mixed-model ANOVAs. In 3000 ms startle amplitudes there was a trend towards a main effect of time, $F_{(1,43)} = 3.35$, $p = .07$, and a trend towards an interaction between time and emotion, $F_{(1,43)}$

= 3.43, p = .07. There was a main effect of emotion: startle amplitudes were higher for negative stimuli (M=12.94) than neutral (M=12.09), $F_{(1,43)} = 4.90$, p = .03. For subsequent analyses examining individual differences in startle response, fear-potentiated startle responses were calculated (i.e. the difference between negative and neutral trials).

Table 4.3

Means and standard deviations of startle reflex amplitudes (mV) and latencies (ms) in mindfulness and control groups.

		Mindfulness Group (N=22)		Control (N=23)	
		T1	T2	T1	T2
	Startle amplitude				
3000ms	Neg	12.88 (11.73)	11.21 (10.87)	16.93 (14.66)	12.70 (10.90)
	Neut	13.13 (12.39)	10.42 (10.21)	16.60 (16.22)	11.79 (10.42)
200ms	Neg	12.42 (14.51)	9.39 (9.75)	15.34 (13.89)	14.01 (12.13)
	Neut	12.55 (14.70)	9.51 (9.97)	16.64 (16.07)	13.29 (11.20)
	Startle latency				
3000ms	Neg	103.1 (5.3)	104.5 (10.0)	101.0 (4.2)	102.5 (8.2)
	Neut	102.7 (9.9)	101.4 (7.0)	101.4 (6.0)	105.5 (12.4)
200ms	Neg	97.0 (9.2)	99.3 (8.6)	96.1 (9.7)	97.3 (6.8)
	Neut	100.9 (13.3)	97.4 (6.9)	96.6 (7.9)	96.9 (6.5)

In 3000 ms startle latencies there were no effects of time and no interaction between time and group, Fs < 2.35, p > .13. 200 ms startle amplitudes and latencies were examined using a 2 (time: T1 vs. T2) x 2 (emotion: negative vs. neutral) x 2 (group: mindfulness vs. control) mixed-model ANOVA, There were no main effects of time or emotion on amplitude, Fs < 2.76, ps > .11, and no interaction between time, emotion and group, Fs < 3.22, ps > .08. There were also no effects of time or emotion, Fs < .37, ps > .56 or any interactions with group on startle latencies, Fs < 1.37, ps > .25.[5]

[5] Due to the null effect of emotion, in further analysis 200 ms startle amplitudes and latencies were collapsed across emotion.

Does mindfulness training improve antisaccade performance?

To compute participants' antisaccade task error rates, saccadic movements were scored as correct or incorrect according to whether they successfully looked towards/away from the image, depending on the cue-word. Participant's error rate was given as a proportion of available trials (out of 16 per trial-type). Error rates and latencies for correct saccades are presented in Table 4.4 (collapsed across stimulus location).

Error rates were entered into a 2 (time: T1 vs. T2) x 2 (trial-type: antisaccade vs. prosaccade) x 2 (emotion: negative vs. neutral) x 2 (group: mindfulness vs. control) mixed-model ANOVA[6]. Results revealed significant main effects of time, $F_{(1, 35)} = 12.79$, $p = .001$, – accuracy at T2 ($M = .20$) was greater than accuracy at T1 ($M = .16$). Participants made significantly more errors on antisaccade ($M = .33$) relative to prosaccade trials ($M = .02$), $F_{(1, 35)} = 93.26$, $p < .001$. A significant trial-type x time interaction, $F_{(1, 35)} = 15.15$, $p < .001$ was characterised by fewer antisaccade errors made at T2 (M = .34) than T1 ($M = .52$), but no change in prosaccade trials, $F_{(1,35)} = 3.34$, $p = .08$.

There was also a trend towards a trial-type x emotion interaction, $F_{(1, 35)} = 3.79$, $p = .06$. At both T1 and T2 there were no differences between negative and neutral prosaccade error-rates, $t\text{'s}_{(21)} < .8$, $p\text{'s} > .42$. In antisaccade trials, participants made significantly more errors to negative than neutral images at Time 1, $t_{(36)} = -2.44$, $p = .02$, but there was no difference between errors on negative and neutral trials at Time 2, $t_{(36)} = -.39$, $p = .70$.

Latencies for correct saccades were entered into a 2 (time) x 2 (trial-type) x 2 (emotion) x 2 (group) mixed-model ANOVA. There was a trend towards a main effect of trial type, with a trend that latencies to make correct antisaccades were ($M = 220.8$) slower than latencies to make correct prosaccades ($M = 199.5$), $F_{(1,36)} = 3.17$, $p = .08$. There were no other significant effects or interactions, $F\text{'s}_{(1,36)} < 2.32$, p's > .14.

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[6] A 2 (time: T1 vs. T2) x 2 (trial-type: antisaccade vs. prosaccade) x 2 (emotion: negative vs. neutral) x 2 (stimulus location: left vs. right) x 2 (group: mindfulness vs. control) mixed-model ANOVA confirmed that there was no effect of stimulus location on task performance, $F_{(1, 37)} = .33$, $p = .57$, and no interactions involving stimulus location. For further analysis, scores were collapsed across left and right conditions.

Table 4.4

Means and standard deviations of anti-saccade task error rates and latencies (for correct eye-movements) in mindfulness and control group.

		Mindfulness Group (*N*=18)		Control (*N*=19)	
		T1	T2	T1	T2
	Error rates				
Antisaccade	Neg	.38 (.23)	.28 (.20)	.41 (.19)	.31 (.20)
	Neut	.35 (.19)	.27 (.20)	.36 (.19)	.31 (.21)
Prosaccade	Neg	.03 (.04)	.03 (.03)	.01 (.03)	.02 (.02)
	Neut	.01 (.02)	.03 (.03)	.03 (.04)	.03 (.04)
	Latencies				
Antisaccade	Neg	231.9 (91.4)	243.0 (86.7)	211.9 (95.9)	197.5 (41.6)
	Neut	234.8 (85.6)	255.5 (84.7)	205.8 (56.5)	193.0 (39.5)
Prosaccade	Neg	199.4 (31.7)	216.7 (46.3)	182.4 (22.3)	191.5 (26.0)
	Neut	200.3 (33.6)	224.0 (50.7)	187.3 (26.4)	197.3 (30.5)

Is baseline dispositional mindfulness associated with heart-rate variability, antisaccade performance or startle responses at Time 1?

There were no significant associations between error-rate nor latencies in prosaccade trials and any self-report scores (see Table 4.4) – prosaccade scores have not been tabulated as low variances meant no associations were observed.

MAAS scores were positively correlated with antisaccade error rate (Figure 4.5), with higher mindfulness scores being associated with an increased antisaccade error rate, $r = .53$, $p < .001$. Additionally, latency was negatively correlated with self-report mindfulness scores, with higher mindfulness scores associated with reduced (faster) latencies to make correct eye-movements and eye-movements overall , $r = -.39$, $p = .004$,).[7]

[7] Separate analysis also investigated the relationship between error-rates and latencies at individual time points. However, due to methodological limitations noted in Bruyer & Brysbaert, 2011 (e.g. large increases

Table 4.5

Pearson's r values for associations between task performance scores and self-report measures of mindfulness, anxiety and attention control.

		Self-report measure at T1				
		STAI	PSWQ	ACS	MAAS	KIMS
Antisaccade Trials						
Error-rate	Neg	.09	.05	.11	.45**	.30
	Neut	.05	-.02	.34*	.45**	.33*
Correct latencies	Neg	.10	.17	-.08	-.16	-.07
	Neut	.13	.09	-.19	-.35*	-.21
All latencies	Neg	.24	.17	-.16	-.41*	-.18
	Neut	.17	.12	-.23	-.51**	-.21

Note: (*) indicates $p < .05$, (**) indicates $p < .01$.

Bivariate correlations examined associations between Time 1 startle amplitudes and latencies and Time 1 self-report scores. Significant associations were observed between larger 3000 ms fear-potentiated amplitudes and increased trait anxiety, $r = .42$, $p = .004$, and increased worry, $r = .50$, $p = .001$. No associations were observed between T1 self-report measures and T1 startle amplitudes or latencies in 200 ms conditions (collapsed across emotion).

in variance, increased Type 1 errors, diminished experimental power), these analyses were considered flawed and are not reported.

Each condition (time x trial-type x emotion) was examined for associations between latency and error-rate in the antisaccade task (latencies used were latencies for all trials, not just correct trials; i.e. the latencies for all the trials used to calculate the error rate). At Time 1, latency and error-rate were associated in antisaccade neutral trials, $r = -.51$, $p < .001$, and negative trials, $r = -.60$, $p < .001$.

Further analysis examined the relationship between the change in error rates and the change in task latencies, There was a significant association in negative antisaccade changes ($r = .43$, $p = .007$) and neutral antisaccade changes ($r =.51$, $p = .001$), i.e error-rate reductions were associated with increases in speed.

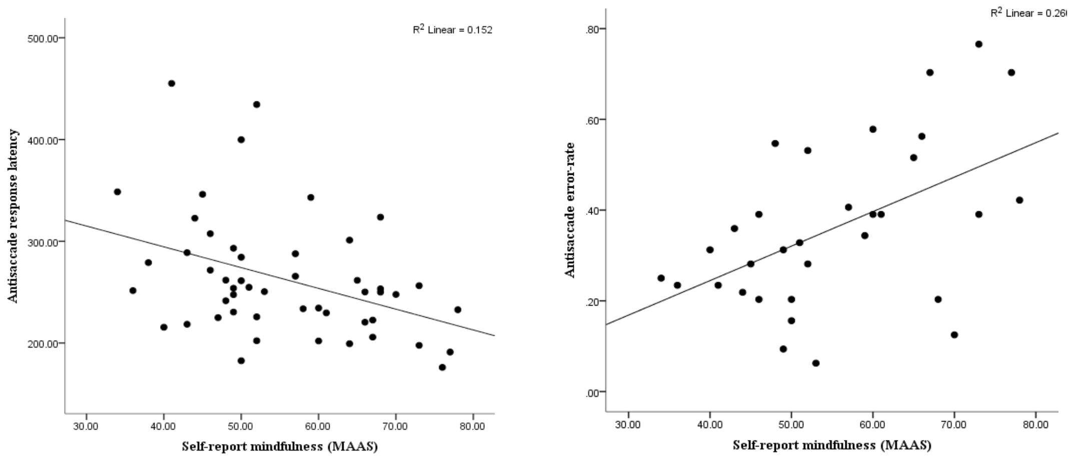

Figure 4.4 Baseline associations between Time 1self-report mindfulness scores and Time 1antisaccade trial latencies and error rates.

Are changes in self-report measures of mindfulness and anxiety associated with changes in startle and antisaccade?

Associations between self-report score changes and changes in antisaccade task performance are presented in Table 4.5. There was a negative relationship between MAAS scores and latencies on prosaccade trials, r = -.46, p = .008, and correct prosaccade latencies, r = -.54, p = .001 such that those participants who experienced greater increases in mindfulness became quicker to make eye movements on prosaccade trials. There were no associations between antisaccade error rate and self-report score changes, *r's* < .30, *p's* > .09.

Bivariate correlational analysis found increases in dispositional mindfulness measured using the MAAS were associated with decreases in 3000 ms fear-potentiated startle amplitude, r = -.35, p = .03, and increases in 3000 ms fear-potentiated startle latency, r = .33, p = .04.

In 200 ms trials (collapsed across emotion), changes in startle latency and amplitudes were not associated with changes in self-report measures of anxiety, mindfulness or attention.

Does mindfulness practice (homework completion) covary with change in self-report mood, mindfulness and startle and antisaccade performance?

Self-report scores. Bivariate correlations found no significant associations were observed in the intervention group between change in any self-report measure and mindfulness amount of practice (number of completed homework sessions), nor between changes in task-performance and amount of practice.

Antisaccade/Startle scores. There were no associations between amount of mindfulness practice and changes in antisaccade measures of performance or changes in startle responses.,

Were changes in threat appraisal associated with changes in attention performance?

Bivariate correlations found no baseline associations between antisaccade error-rates/ latencies (correct and total trials) and startle amplitudes/latencies, and no associations between change in antisaccade error-rates/latencies and change in startle amplitudes/latencies.

Discussion

The distinction between threat-appraisal and attention allocation mechanisms is important in neurocognitive models of emotion processing and anxiety. The present study examined whether mindfulness led to improvements in threat appraisal (measured by a startle probe) and attention to threat distractors (in an antisaccade task).

The effect of mindfulness on threat-appraisal

It was predicted that mindfulness meditation would allow more adaptive allocation of attentional resources, resulting in increased goal-related focus. Therefore, participants benefiting from mindfulness practice would demonstrate reduced prepulse inhibition (i.e. increased startle amplitudes at Time 2) and reduced fear-potentiated responses. No effect of mindfulness practice was observed on threat-appraisal measured using the startle probe.

Participants who demonstrated increased dispositional mindfulness also demonstrated decreased fear-potentiated startle amplitude, and increased fear-potentiated startle latency. The finding that the ‘more mindful’ an individual becomes, the less fear-potentiated startle activity is demonstrated, is consistent with the notion that more mindful individuals are better able to efficiently allocate attentional resources towards maladaptive stimuli (i.e. less likely to demonstrate dysfunctional threat-responses). However, this finding should be interpreted with caution, particularly given that i) baseline dispositional mindfulness was not related to fear-potentiated startle response, and ii) there were no between-group effects of mindfulness meditation (on fear-potentiation or prepulse inhibition). Several possibilities exist as to why there was no effect of mindfulness practice on startle potentiation and prepulse inhibition despite the observed effects of a less extensive practice on attention control (Chapter 3), and these will be taken in turn. Firstly, that increased mindfulness does not cause changes in threat-processing, as measured by the startle task. Although extensive evidence demonstrates that mindfulness improves executive control (e.g. Moore & Malinowski, 2009) and the role of maladaptive attention control in biased threat-processing (see Bar-Haim et al., 2007), as of yet there is no clear link between mindfulness meditation and improvements in threat-processing.

Secondly, findings from the startle probe may not accurately reflect threat-processing mechanisms in healthy individuals. It is possible that individual differences in habituation to repeated presentations of stimuli within experimental blocks may reduce the sensitivity of the startle task as a measure of threat-processing (although IAPS stimuli have been shown to modulate startle and other indices of affective experience in other studies [see Lang, Bradley, & Cuthbert, 2008] and previous evidence has demonstrated repeated stimuli have maintained robust effects; see Grillon & Baas, 2003). Notably, our study did observe larger startle amplitudes in towards negative stimuli, and associations between greater fear-potentiated responses and increased anxiety/worry. These results suggest that maladaptive responses to threat caused by anxiety were successfully detected by the task. Continued research using the startle probe should examine the validity of task designs using repeated stimulus presentation, particularly within experimentally validated stimuli sets such as the IAPS.

Thirdly, the extent to which mindfulness meditation practice can induce substantial dispositional differences in mindfulness (such as those seen in naïve vs. experienced practitioner comparisons) is still unknown. Although our study design included an in-session acute mindfulness practice in order that any changes induced by mindfulness practice would be optimally registered, further research should examine whether short-courses of mindfulness practice can actually change robust dispositional measures of anxiety/worry/mindfulness.

The effect of mindfulness on attention to threat

Antisaccade error-rates decreased in all participants across time, but there was no effect of mindfulness practice on task-performance measured using error-rate or latency. There are several possible explanations for null results; and these will be taken in turn.

Firstly, practice-induced improvements in attention functioning might not impact threat-processing mechanisms. However, findings of associations between baseline self-report mindfulness and antisaccade performance suggest this is not the case. The lack of observed effects of mindfulness practice/dosage further suggest that this intervention did not impact complex inhibition processes examined in the antisaccade task – despite participants receiving more teacher-contact time than in the previous intervention (Chapter 3) with 5 group sessions (vs. 3 in Chapter 3) and a more robust daily practice routine – as well as similar in-session mindfulness instruction. This (null) finding suggests that the inhibitory processing indexed in the antisaccade task is functionally different from the executive attention indexed with the ANT (see Chapter 3).

This is supported by a lack of change in any self-report measure – similar findings were observed in Chapter 3. That there were no effects on two robust self-report measures of mindfulness (MAAS and KIMS) may indicate that either i) that mindfulness meditation does not affect anxiety, worry or dispositional mindfulness (in contrast with evidence from Vøllestad et al., 2012), ii) that mindfulness imparted through meditation-intervention sessions was minimal (and consequently had no effect on basic self-report measures, particularly in the healthy-volunteer population), or iii) that the intervention was training an attention-technique other than mindfulness (i.e. not measured by the MAAS, KIMS, nor ACS). Despite the lack of 'experiential' change in mindfulness, the intervention used in study 3 did seek to improve on that used in study 2 in several ways. Firstly, the total length of the intervention was longer, allowing more time for mindfulness practice. Secondly, participants were actively encouraged to practice every day, using an online monitoring task. Thirdly, previously separate OM/FA mindfulness aspects were combined in a more 'rounded' mindfulness intervention.

An alternative is that mindfulness-induced changes had affected executive attention allocation, but the small degree of change (i.e. not measurable on self-report scales) did not influence (non-dysfunctional) biased attention to threat. Reliable changes in threat-processing were not observed in the antisaccade task nor the startle probe (perhaps due to strong-situation; see Lissek, Pine & Grillon, 2006).

The association between dispositional mindfulness and baseline antisaccade performance suggests mindfulness does impact attention – although the nature of this relationship requires clarification (individuals with higher mindfulness were quicker to make antisaccades, but made more errors). A standard interpretation of antisaccade results (i.e. increased mindfulness leads to reduced performance efficiency but increased performance effectiveness) is paradoxical – and a false-positive is unlikely given strength/parity of the finding across negative and neutral stimulus conditions. Therefore, possible interpretations for this pattern revolve around the nature of 'mindful attention', and its implications for antisaccade performance.

Can attentional bias be approached 'mindfully'?

Previous cross-sectional studies have found that individuals who make faster antisaccades also tend to make fewer errors (i.e. are 'better' at the task), and the present findings were no exception (Ansari et al., 2008; Crevits, Van den Abbeele, Audenaert, Goethals, & Dierick, 2005; Kristjánsson et al., 2001). Improvements in task performance should therefore be reflected in faster antisaccades and fewer errors (rather than the observed faster antisaccades yet *more* errors) observed in participants with higher dispositional mindfulness.

One possibility is that differences in dispositional mindfulness impact task *motivation* instead of task performance: reflected by the manner in which individuals approach all trials. Mindfulness emphasizes the importance of 'non-judgmental' thinking, and it may be that participants were less inclined to devote cognitive resources to 'wrenching' their attention from threat-related stimuli. This is in line with recent arguments that mindfulness-training paradigms should be regarded with caution due to possibly confounds caused by individual differences in attentional effort (Jensen, Vangkilde, Frokjaer, & Hasselbalch, 2012). Thus further research should assess the usefulness of the antisaccade task as a suitable measure of inhibitory processes (see Robinson, Krimsky, & Grillon, 2013, for related discussion on the effects of anxiety on inhibitory processes).

The relationship between threat-appraisal and attention-to-threat, and implications for mindfulness

These findings indicate that threat-appraisal and attention-to-threat, as measured by the startle probe and antisaccade task, are distinct mechanisms and do not covary. This pattern does not support predictions from models (e.g. Mogg & Bradley, 1998; Mathews & Mackintosh, 1998) that suggest that attentional allocation to threat is dependent on an individual's i) appraisal of a stimulus as threatening and ii) relevance of threat to current goal.

Furthermore there were no reliable effects of mindfulness meditation on threat-processing in either cognitive task. Although there was some evidence for an association between dispositional mindfulness and threat-appraisal/attention-to- threat, there was no evidence that this relationship was common to either threat-processing mechanism. The correlational nature of this finding significantly limits the extent to which conclusions about the impact of mindfulness on maladaptive threat-processing can be drawn. However, this association, in conjunction with evidence that mindfulness meditation can improve executive control (Chapter 3), warrants further examination of the relationship between mindfulness and maladaptive threat-processing biases (i.e. beyond functional threat-processing mechanisms in healthy individuals).

The present study used findings from Chapter 3 to introduce a pragmatic mindfulness intervention, and used robust, objective cognitive/psychophysiological tasks to index threat-appraisal and attention-to-threat. However, the relatively small sample size may have contributed to small (null) changes in mindfulness on robust self-report measures. Additionally, it is unclear whether changes in threat-appraisal are due to dispositional mindfulness changes (in contrast to self-report findings) or mindfulness skills 'induced' through the in-session practice. Future research could address this by explicitly examining acute, in-session mindfulness and its effect on attention and anxiety.

In summary, the current intervention found no effect of practice frequency and there were no dispositional changes in mindfulness or attention control, despite a substantial increase in intervention length and rigour from the previous ANT study. While both studies found effects on threat-processing biases, it is possible that these were induced by the acute in-session mindfulness practice rather than more substantial changes in dispositional mindfulness (which, as in Chapter 3, were not observed). A significant proportion of previous findings stem from comparisons of novice vs. experienced meditators – and it may be that acute in-session practice induces effects similar to that which practiced meditators may experience on a dispositional level. Indeed, clinical mindfulness interventions often require significant time commitment (Kocovski, Segal & Battista, in Didonna, 2009) beyond 8-weeks, and the extent to which acute practices reflect long-term dispositional changes is still unclear. Thus, further research explicitly examining the impact of an acute, in-session, mindfulness practice may provide insights into i) the impact of mindfulness on attentional biases and ii) whether changes in attentional biases can protect against/modulate anxiety.

Chapter 5

The effect of open-monitoring and focused attention practice on self-report, autonomic and neuropsychological responses to CO_2 inhalation

Introduction

Previous chapters have examined specific 'pathways of impact' through which mindfulness meditation may modulate cognitive dysfunction and emotion processing in anxiety. In study 2 both OM and FA practice increased executive control in a computerized attention network test, whilst study 3 suggested that mindfulness can reduce maladaptive threat-processing (i.e. threat-avoidance). Taken together these results suggest that mindfulness may protect against/reduce maladaptive cognitive biases in anxiety.

However, despite efforts in study 3 to improve the fidelity of the intervention and monitor homework, the effects of practice on primary outcome measures of dispositional mindfulness (MAAS, KIMS) were non-significant i.e. practice did not improve mindfulness. Thus the present study moved from examining the effect of short training courses and instead examined the effect of acute practice (within the test session) on mood and emotion processing. Effects immediately after a brief induction may be reflective of potential dispositional changes induced through extensive mindfulness practice.

Study 2 and study 3 did not reveal strong effects of stimulus valence on attention network function, startle, or antisaccade performance. These results may in part reflect the use of healthy/low-anxious participants in whom levels of trait anxiety and threat processing may already be adaptively low and resistant to modification through mindfulness practice. Therefore this final study examined the effect of OM and FA on mood, autonomic arousal and attention to threat in healthy volunteers subjected to a novel anxiety induction procedure – the 7.5% CO_2 inhalation model of generalized anxiety.

The 7.5% CO_2 inhalation model of generalized anxiety

The development of healthy-volunteer experimental models of anxiety can provide validation of findings in anxious populations when investigating mechanisms of change for anxiety treatments (Bailey, Dawson, Dourish, & Nutt, 2011). Inhaling a mixture of 92.5% normal air enriched with 7.5% CO_2 for 20-minutes has been shown to reliably increase subjective feelings of anxiety (e.g. anxiety, tension, worry: Bailey, Kendrick, Diaper, Potokar, & Nutt, 2006; Bailey, Papadopoulos, & Nutt, 2009) and autonomic arousal (e.g. heart rate and blood pressure: Bailey, Argyropoulos, Kendrick, & Nutt, 2005; Bailey et al., 2011; Garner et al., 2011). As such this model is considered to provide a putative experimental model of generalized anxiety (Seddon et al., 2011), that qualitatively and quantitatively differs from 'panic-like' symptoms induced by other anxiety models (e.g. single-inhalation of 35% CO_2 model of panic; Esquivel, Schruers, Kuipers, & Griez, 2002; Richey, Keough, & Schmidt, 2012).

Recent investigations have indicated that the 7.5% CO_2 challenge may induce dysfunctional attentional patterns observed in anxious populations. It can increase selective attention to emotional faces (Cooper et al., 2011), increase erroneous eye-movements towards threat pictures in an antisaccade task (Garner, et al., 2011) and increase hypervigilance (alerting and orienting attention network function) in the ANT (Garner, Attwood, Baldwin, & Munafò, 2012).

Inhalation of 7.5% CO_2 provides a novel experimental model of generalized anxiety that can be used to evaluate pharmacological and psychological interventions. To date several drugs have been evaluated using the 7.5% CO_2 model (including benzodiazepines, SSRIs and SNRIs, see Bailey et al., 2011, for a review), but the model has yet to be used to evaluate any psychological interventions.

Mindfulness and the 7.5% CO_2 challenge

The promising nature of the 7.5% CO_2 challenge, with consistent effects across autonomic, subjective mood and cognitive/emotional aspects of anxiety indicate its suitability for evaluating mechanisms of change in mindfulness-based anxiety treatments.

Mindfulness meditation has previously been shown to reduce physiological indicators of stress such as reduced blood pressure (Carlson, Speca, Faris, & Patel, 2007; Palta et al., 2012), reduced salivary cortisol (Carlson et al., 2007; Jensen et al., 2012) and reduced heart-rate (Fadel Zeidan et al., 2010). Therefore, mindfulness interventions may protect against 7.5% inhalation-induced autonomic measures of anxiety by reducing blood-pressure, heart-rate and heart-rate variability.

Other (pharmacological) treatment methods have reduced self-report anxiety/worry during the 7.5% CO_2 challenge, but have shown no moderation of increased autonomic anxiety measures – suggesting that reductions in subjective anxiety/worry are 'downstream' of physiological inhalation effects (Bailey et al., 2011). Mindfulness meditation encourages deliberate, objective attention to internal and external stimuli. It can lead to reduced negative affect (Brown & Ryan, 2003; Chadwick et al., 2008; Chambers et al., 2007; Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010) and more adaptive responses towards stress (Davidson et al., 2003) as well as reduced defensive responses towards threat (Kashdan, Afram, Brown, Birnbeck, & Drvoshanov, 2011; Niemiec et al., 2010). Increased mindfulness may modulate self-report anxiety through reduced negative affect towards physiological responses induced through CO_2 inhalation, in line with evidence that mindfulness modulates internal perceptions of (chronic) pain through a non-elaborative mental stance (Brown & Jones, 2010; Grant, Courtemanche, & Rainville, 2011; Zeidan, Grant, Brown, McHaffie, & Coghill, 2012; Zeidan et al., 2011).

In addition, maladaptive attention to threat observed in clinical/sub-clinical anxiety (see Bar-Haim et al., 2007, for a review) and induced in healthy-volunteer models (Cooper et al., 2011; Cornwell et al., 2012; Garner, et al., 2011; Garner et al., 2012) may be reduced by mindfulness. Mindfulness-interventions have been related to improved attentional functioning (study 2, Jha et al., 2007; Napoli, Krech, & Holley, 2005; Ortner et al., 2007; Tang et al., 2007; Zeidan et al., 2010), and mindfulness may regulate maladaptive attentional biases induced by CO_2 challenge (e.g. Garner et al. 2011). Study 2 found comparable effects of two types of mindfulness-based meditation (FA and OM) on executive attention in healthy individuals. Examination of FA vs. OM using the 7.5% model may provide evidence for differential effects in high-anxious individuals, with implications for targeted anxiety interventions (e.g. MBSR/MBCT). Thus the aim of the current study was to examine the effects of FA and OM practice on an antisaccade threat-processing task alongside autonomic and self-report measures of anxiety.

Experimental hypotheses

There are several possible pathways through which mindfulness can impact 7.5% CO_2-challenge induced anxiety: reduced physiological markers of stress, or reduced negative affect, or reductions in dysfunctional threat-appraisal/attention-to-threat. Therefore the following findings are predicted:

i) Mindfulness groups will have a reduced CO_2-induced increase in autonomic markers of anxiety (heart rate, systolic/diastolic blood pressure, heart-rate variability) compared to relaxation controls
ii) Mindfulness groups will have a reduced CO_2-induced increase in self-report measures of state-anxiety and negative affect compared to relaxation controls, particularly in OM (due to monitoring/acceptance of internal/external anxiety cues)
iii) Mindfulness groups will show reduced maladaptive attention-to-threat on the antisaccade threat-processing task compared to relaxation controls, particularly in FA (due to active redirection of attention to goal-related tasks).

Method

Participants

Consistent with previous CO_2 studies (Garner et al. 2011, 2012) 93 participants were recruited through the University of Southampton online recruitment service (Psychobook). Participants were screened for general physical and mental well-being using a pre-test neuropsychiatric diagnostic interview based on the Mini International Neurospychiatric Interview (Sheehan et al., 1998). A preliminary version of this was delivered via phone a week before participation, and a further interview was completed at the test session. Exclusion criteria included recent use of medication (8 weeks excluding aspirin, paracetamol or contraceptive pills), pregnancy, risk of respiratory condition, risk of cardiovascular disease, risk of psychiatric illness, under or over-weight (i.e. BMI between 18-28), history of drug dependence and recent use of alcohol (breath test), and 33 participants met exclusion criteria..

60 (20 male, 40 female) participants satisfied inclusion criteria, of which 11 participants withdrew during the study. 49 participants were included in analysis, with a mean age of 21.0 years (*SD* = 3.2). Participants received course credits or a £21 equivalent.

Eligible participants were randomly assigned to one of three groups: focused attention meditation (*N*=26), open-monitoring meditation (*N*=23), and a relax-as-usual control group (N=11)[8]. There were no between-group differences in gender, χ^2 = .86, p = .64, or age, $F_{(2,57)}$ = 2.75, p = .07.

Design

Participants completed a single test session in which they completed behavioural and self-report measures during inhalations of 7.5% CO_2 enriched air (21% O2; balance N2) and normal air through an oro-nasal face mask. Participants were blind to gas and training condition, and CO_2 vs. air inhalation order was counterbalanced across participants.

Measures

Physiological measures. Heart-rate and systolic/diastolic blood pressure were examined using Omron-M6 monitoring devices (Medisave, UK). Heart-rate variability was measured using electrocardiography taken from twin electrodes attached to both wrists, at a sample-rate of 1000Hz (MP150-amplifier and AcqKnowledge 3.8.1 softward, Biopac-Systems, Goleta, CA). HRV outputs were the average standard deviation of peak-to-peak beat intervals (SDNN) and sympathetic-vagal system activation ratio, as well as mean heart-rate during HRV data recording.

Self-report measures. A number of self-report measures were used for which detailed information has been provided (Chapter 3): the Attention Control Scale (ACS; Derryberry & Reed, 2002, α = .78), the State-Trait Anxiety Inventory (STAI/SSAI; Spielberger et al., 1983, α_T = .83, α_S = .88), the Penn State Worry Questionnaire (PSWQ; Meyer et al., 1990, α = .91) and the Mindfulness Attention Awareness Scale (MAAS; Brown & Ryan, 2003, α = .74).

Other questionnaire measures included are as follows:

Five Factor Mindfulness Questionnaire (FFMQ; Baer et al., 2008)[9]. The FFMQ is measures 39-items of mindfulness on a 5-point likert scale (Appendix H). The measure consists of five subscales that assess dispositional mindfulness through daily life:

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[8] Although effects of CO2-inhalation are well-known and robust, a small sample of control participants was recruited to ensure that any extraneous variables associated with particular study context were accounted for.

[9] FFMQ was used instead of the KIMS (Baer et al., 2004) as recent studies suggested that it provides a similar measure of extra-attentional facets of mindfulness, but is not based on dialectical behaviour therapy principles, unlike the KIMS (see Baer et al., 2008).

observing (noticing or attending to internal/external experiences), *describing* (ability to verbally label experiences), *acting with awareness* (attending to current goal/activity), *non-judgement of inner experience* (a non-evaluative stance towards cognitions and emotions) and *non-reactivity to inner experience* (noticing internal cognitions/emotions but not reacting to them). Scores on subscales range from 8-40, with higher scores reflecting increased mindfulness. The present sample reported good internal reliability, α = .84.

Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988). The PANAS (Appendix P) is a 20-item 5-point likert scale measure of current mood (i.e. positive and negative affect), and has been widely used in previous CO_2 inhalation studies (e.g. Garner et al., 2012). Participants are asking to what extent they feel a range of emotions right now (e.g. interested, strong, inspired) range from 1 (very slightly or not at all) to 5 (extremely). Scores range from 10-50, with higher scores indicating increased positive affect and reduced negative affect. 10-item subscales (PANAS-P and PANAS-N) examine independent positive and negative subscales, and demonstrate good internal consistency, PANAS-P α = .89, PANAS-N α = .85.

Antisaccade Task. A version of the antisaccade task used in the previous experiment (Chapter 4; Fig 4A) examined threat-processing biases in participants. This task has been used in previous CO_2 studies (Garner et al 2012) and provides independent measures of efficiency and effectiveness (presented through antisaccade latency and error-rate, respectively). Each inhalation had 24 antisaccade trials and 24 prosaccade trials, each trial-type having 12 negative and 12 neutral stimuli trials. Trials were counter-balanced within-participants for stimuli location, probe location and probe type (up/down).

Procedure

Eligible participants attended a single test session. Participants completed baseline self-report measures (STAI-T/S, MAAS, ACS, PSWQ, ASI, PANAS, KIMS, VAMS) and measures of autonomic arousal (HR, SBP, DBP) and were assigned to either OM or FA group, with a training group (matched for gender).

Participants were then asked to engage in either a FA or OM practice for 10 minutes (detailed below) or to relax (also for 10 minutes) – see Appendix N for a full procedural diagram. After practice, participants completed visual analogue self-report measures and autonomic arousal measures, before putting on the oro-nasal facemask and completing the first 20-minute inhalation session (order single blind and counterbalanced across participants).

The inhalation then began again and participants completed the antisaccade task (see Fig. 5A) after 10 minutes of the inhalation, before the mask was removed and participants completed autonomic measures and STAI-S, PANAS and VAMS measures.

Following a 30-minute rest period (enabling residual inhalation effects to subside) the protocol was repeated to counterbalance CO_2/air order effects. All participants were contacted by the research team 24 hours after the experiment to record any adverse events following the inhalation procedure.

Acute mindfulness practice

Training sessions comprised 10-minute audio mp3-recordings (Appendix O) of guided mindfulness practices delivered by an NHS consultant psychiatrist with extensive experience in mindfulness practice (>2000 hours) and clinical use of mindfulness with patients (since 2000).

Control Group. Control group participants were asked to use the time to relax before completing cognitive and inhalation tasks. They were in the same environment as both meditation groups, but the speakers through which the recordings were played remained off.

Focused Attention Meditation (FA). The FA practice involved directing participants to concentrate their attention towards a fixed point, suggested to be the sensations of their breathing in a specific place (such as the tip of the nose). Participants were encouraged to *"make a decision to stay with this place for the duration of this exercise rather than moving your awareness from one place to another"* and to *"maintain this focus, and if the mind wanders, gently return the mind to this place."* Notably, participants were encouraged to notice any wayward attention (i.e. towards anything other than sensations of breathing) and *"firmly but gently"* return their focus towards their initial focal-point.

Open-monitoring meditation (OM). OM practice involved a similar focusing of attention towards a singular point (sensations of breathing) for 4 minutes, before participants were encouraged to *"allow a sense of awareness of the breath and physical sensations in the body generally to gradually expand,"* to include, respectively, additional bodily physical sensations, sensations of sound, sight and smell, and internal stimuli (i.e. emotions and cognitions). Participants were instructed to accept, in a non-evaluative manner, any changes that occurred - *"whatever sense of comfort or discomfort, any* *emotions you feel right now, allowing them to become part of your field of awareness right now."*

Data Pre-analysis

Saccadic data was subjected to the same methodology as in Chapter 4; scored manually by a researcher who was blind to trial-type/training condition. Incomplete or anticipatory saccades (occurring before 100ms) were excluded, as were scores from participants who withdrew from the experiment ($N = 4$). Participants deemed to have excessive error-rates (see Garner, et al., 2011) according to visual histograms were also excluded ($N = 2$), and error-rates/latencies were examined for assumptions of normality using Shapiro-Wilks' tests, *all ps* > .05. Heart-rate variability scores were also coded and filtered using the same methodology as in Chapter 4 (Berntson et al., 1997; Hejjel & Kellenyi, 2005).

Results

Group Trait Characteristics

To check if groups were matched on trait measures of anxiety, mindfulness and attention control; baseline self-report measures (Table 5.1) were entered into one-way ANOVAs. There were no differences between groups on any measures, $Fs_{(2,53)} < 1.30$, *p*s > .28 (including subscales of FFMQ, $Fs_{(2,53)} < .61$, *p*s > .55). Scores were within the range typical of non-clinical, non-anxious samples (FFMQ: Fisak & von Lehe, 2012, previous chapters).

Table 5.1. Group Trait Characteristics (Mean and SD).

	Focused attention	Open-monitoring	Control
STAI	32.3 *(6.3)*	32.4 (*6.5*)	33.5 *(4.7)*
MAAS	59.6 *(9.8)*	56.7 *(8.7)*	57.0 *(7.1)*
FFMQ	128.2 *(16.0)*	127.8 *(11.9)*	128.2 *(15.7)*
ACS	47.4 *(7.0)*	49.6 *(7.8)*	48.6 *(8.5)*
PSWQ	43.0 *(10.0)*	38.5 *(11.7)*	*41.0 (12.1)*

Effects of OM and FA on 7.5 % CO_2 -induced self-report anxiety and autonomic arousal

Table **5.2** presents self-report state anxiety (SSAI), positive and negative affect (PANAS) and autonomic anxiety measures (SBP, DBP, HR) as obtained at several points throughout the experiment: baseline, after CO_2 inhalation and after air inhalation. One-way ANOVA confirmed there were no differences between groups at baseline measures, *F*s < 1.8, *p*s > .16.

Table 5.2

Baseline and pre/post inhalation self-report and autonomic anxiety measures (Mean and *SD*) by training group.

	FA			OM			Control		
	Baseline	CO_2	Air	Baseline	CO_2	Air	Baseline	CO_2	Air
SSAI	32.4 (7.8)	44.1 (9.6)	33.8 (8.2)	32.7 (6.5)	47.0 (11.0)	34.3 (6.8)	33.4 (5.3)	57.8 (11.6)	38.7 (7.3)
PANAS (positive)	26.6 (5.6)	21.4 (6.5)	23.5 (6.2)	30.6 (5.5)	21.8 (7.4)	26.1 (7.6)	26.0 (6.4)	15.3 (5.8)	20.0 (5.9)
PANAS (negative)	11.5 (3.1)	15.6 (4.9)	11.4 (2.4)	12.9 (3.8)	17.0 (6.5)	11.9 (3.4)	11.3 (1.4)	23.1 (10.0)	11.6 (1.6)
SBP	117.8 (11.5)	129.3 (15.6)	112.4 (11.7)	117.1 (17.1)	127.9 (12.5)	116.1 (9.8)	116.7 (8.1)	117.4 (18.8)	115.1 (5.2)
DBP	67.2 (8.7)	78.5 (13.4)	71.2 (7.8)	72.7 (15.2)	75.9 (9.7)	75.0 (7.2)	69.7 (11.5)	72.9 (10.1)	73.4 (12.1)
HR	71.3 (7.9)	87.4 (18.2)	71.3 (7.8)	75.3 (11.0)	86.9 (21.8)	74.1 (15.4)	75.6 (9.3)	83.1 (11.4)	67.7 (14.6)
SDNN	-	.15 (.08)	.13 (.08)	-	.12 (.08)	.11 (.07)	-	.23 (.18)	.21 (.12)
SV	-	.62 (.27)	.85 (.58)	-	.55 (.26)	.83 (.67)	-	.97 (.83)	1.3 (.95)

The effect of mindfulness on self-report anxiety (SSAI).

CO_2 vs. air effects were examined using a mixed-model 3 (group: FA vs. OM vs. Control) x 2 (inhalation order: gas vs. air first) x 2 (inhalation: CO_2 vs. air) ANOVA.

Post-hoc examination of the main effect of inhalation, $F_{(1,50)} = 107.29$, $p < .001$ with higher scores in the CO_2 condition (M=47.8) than the air condition (M = 34.9). This increase was subsumed by a trend towards a inhalation x group interaction, $F_{(2,49)} = 2.60$, $p = .08$. There was no interaction involving inhalation order, Fs < 1.18, ps > .31.

Post-hoc analysis of the inhalation by group trend found that groups did not differ in self-report state anxiety after air inhalation, $F_{(2,51)} = 1.43$, $p = .24$, but that there was a significant group difference in anxiety after CO_2 inhalation, $F_{(2,53)} = 6.57$, $p = .003$. Multiple comparisons of CO_2-induced anxiety (i.e. the difference between anxiety in CO_2 and air inhalations), with Tukey HSD correction, showed no difference between FA and OM groups, $p = .61$, but that the relaxation group reported higher anxiety than both FA, $p = .004$, and OM, $p = .02$. Thus CO_2-induced anxiety was significantly lower in FA and OM groups compared to the relaxation control group (Figure 5.1).

The effect of mindfulness on positive and negative affect.

Training effects on CO_2-induced positive-affect were examined using a mixed-model 3 (group: FA vs. OM vs. Control) x 2 (order: gas vs. air first) x 2 (inhalation: CO_2 vs. air) ANOVA. A main effect of inhalation, $F_{(1,50)} = 24.60$, $p < .001$ found that positive affect was significantly lower after CO_2 inhalation (M = 20.6) than after air (M = 24.3). There were no interactions involving group or inhalation order, Fs < 1.39, ps >.26.

A similar 3 x 2 x 2 ANOVA examined training effects on CO_2-induced negative affect. A main effect of inhalation, $F_{(1,50)} = 55.90$, $p < .001$ was driven by higher negative affect in CO_2 inhalation (M = 17.3) than air (M = 11.7). This difference was subsumed by a significant inhalation x group interaction, $F_{(2,48)} = 3.43$, $p = .04$.

Post-hoc analysis of the inhalation by group interaction found that there were no significant differences between groups after air inhalation, $F_{(2,52)} = .17$, $p = .85$, but a significant between-groups difference after CO_2 inhalation, $F_{(2,54)} = 5.13$, $p = .009$. Multiple comparisons of CO_2-induced anxiety, with Tukey HSD corrections, found this interaction was driven by significantly higher negative affect in relaxation compared to both OM ($p = .04$) and FA ($p = .007$).

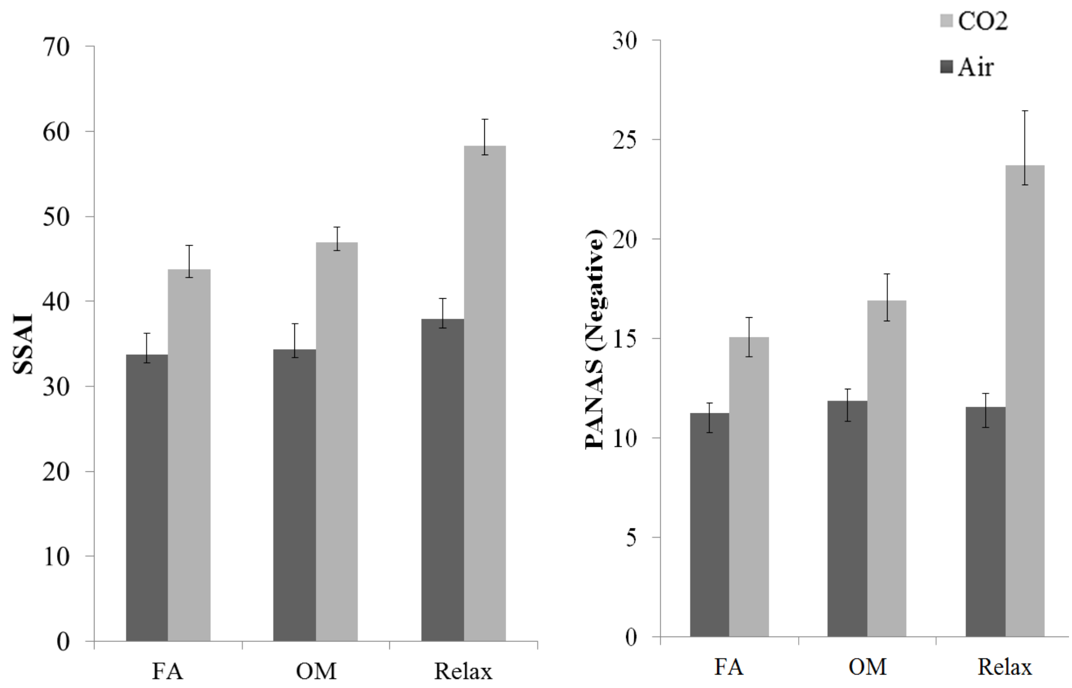


Figure 5.1. Focused attention and open-monitoring mindfulness interventions significantly reduced state-anxiety and negative affect during 7.5% CO_2 challenge, compared to relaxation.

The effect of mindfulness on autonomic measures of anxiety.

Training effects on autonomic measures of anxiety were examined using mixed-model 3 (group: FA vs. OM vs. Control) x 2 (inhalation order: gas vs. air first) x 2 (inhalation: CO_2 vs. air) ANOVAs.

Heart rate: A main effect of inhalation was observed on heart-rate, $F_{(1,48)} = 45.05$, $p < .001$, with significantly higher HRs during CO_2 inhalations ($M = 85.3$) than air ($M = 71.9$) . A non-significant trend was demonstrated towards a group x inhalation x order interaction, $F_{(2,58)} = 2.97$, $p = .09$.

Systolic Blood Pressure: Similarly, a main effect of inhalation, $F_{(1,48)} = 31.67$, $p < .001$ was characterised by increased SBP in all groups after CO_2 ($M = 126.5$) vs. air ($M = 114.3$). A non-significant trend was demonstrated towards a significant inhalation x group interaction, $F_{(2,48)} = 2.70$, $p = .08$.

Diastolic Blood Pressure: A trend towards a main effect of inhalation, $F_{(1,48)} = 3.42$, $p = .07$, was characterised by a trend towards an inhalation x group interaction, $F_{(1,48)} = 2.44$, $p < .10$. One-way ANOVAs found no between-group differences in either inhalation, *F*s < .73, *p*s > .31. Post-hoc t-tests found no differences between anxiety in CO_2

and air inhalations in OM or control, *t*s < .52, *p*s > .61, and a significant decrease in anxiety in FA training group, $t_{(23)} = -2.94$, $p = .007$.

Heart-rate variability (HRV): HRV data was entered into a 2 (inhalation: air vs. CO_2) x 3 (group: FA vs. OM vs. relax) mixed-model ANOVAs to investigate the effects of group and inhalation on heart-rate variability measures, and mean HR during HRV measurement. No interactions involving group were observed, *F*s < .96, *p*s > .39. There was a main effect of inhalation on mean HR, $F_{(1,48)} = 26.02$, $p < .001$, and SDNN $F_{(1,48)} = 3.93$, $p = .05$ and a trend towards a main effect in SV balance, $F_{(1,48)} = 5.03$, $p = .07$. Participants in CO_2 inhalations had higher SDNN ($M = .16$) than air ($M = .14$), lower SV balance ($M = .69$) than air ($M = .89$) and higher mean HR ($M = 78.5$) than air ($M = 70.6$), see Figure 5.2.

Additional one-way ANOVAs investigating differences in heart-rate variability during training sessions found no differences between groups in either pre-inhalation training session, *Fs* < 1.75, *p*s > .18.

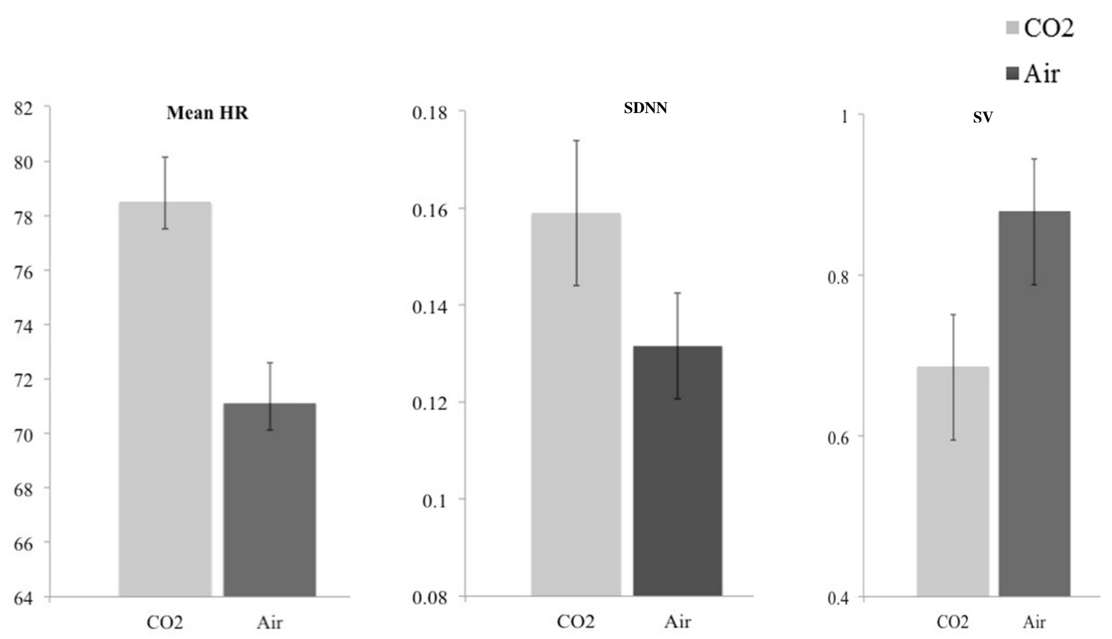


Figure 5.2 CO_2-induced changes in measures of heart-rate variability (vs. air).

Associations between CO_2-induced anxiety and dispositional self-report scores.

Bivariate Pearson's correlations examined the associations between self-report trait measures of mindfulness, anxiety and attention control, and CO_2-induced anxiety (i.e. CO_2

vs. air difference). Due to the large number of correlations tested, significance value corrections were applied to reported correlations (see Curtin & Schulz, 1998)[10].

Greater MAAS scores were associated with greater effects of CO_2 (vs. air), $r = .46$, $p = .001$. There were no other associations between self-report dispositional measures and anxiety scores, *r*s < .19, *p*s > .03.

Further analysis examined associations between CO_2-induced anxiety and CO_2-induced changes in autonomic measures (heart-rate, SBP, DBP, HRV). All results were non-significant, *r*s < .23, *p*s > .09. This analysis was repeated within groups, with no significant associations.

Does mindfulness affect attention-to-threat (antisaccade error-rates and latencies) in CO_2 and air inhalations?

To compute a participant antisaccade error rate, saccadic movements were scored as correct or incorrect according to whether they successfully looked towards/away from the image, depending on the cue-word. A participant's error rate was given as a proportion of available trials (out of 24 per trial-type). Two participants were excluded from analysis due to excessively high error-rates in prosaccade trials (approaching 50%), indicating either i) miscomprehension of task goals or ii) an inappropriate strategy for task completion. Error-rates for antisaccade tasks collapsed across direction (left vs. right) and inhalation order (air first vs. CO_2 first) are presented in Table 5.3.

Error-rates were entered into a 2 (inhalation: CO_2 vs. Air) x 2 (trialtype: pro vs. anti) x 2 (emotion: negative vs. neutral) x 2 (order: air-then- CO_2 or CO_2-then-air) x 2 (stimuli location: left vs. right) x 3 (mindfulness group: FA vs. OM vs. control) ANOVA. There were no effects or significant interactions involving stimuli location so it was subsequently removed as a within-subjects factor, and scores were collapsed across stimulus location.

	Focused Attention		Open-monitoring		Relax	
Error-rates	CO_2	Air	CO_2	Air	CO_2	Air

[10] Significance values were adjusted according to the number of correlations in each comparison, using the formula: $p' = 1 - (1-p)^{1/k}$, when p = standard significance value, p' = adjusted value, and k = number of comparisons.

Antisaccade	Neg	.46 (.27)	.43 (.25)	.58 (.23)	.45 (.22)	.37 (.21)	.29 (.24)
	Neut	.49 (.29)	.44 (.26)	.58 (.24)	.44 (.22)	.47 (.29)	.29 (.23)
Prosaccade	Neg	.02 (.04)	.04 (.05)	.05 (.05)	.03 (.03)	.05 (.05)	.02 (.03)
	Neut	.04 (.05)	.03 (.06)	.03 (.04)	.04 (.04)	.03 (.03)	.03 (.03)
Latencies							
Antisaccade	Neg	186.7 (40.7)	210.4 (49.6)	178.2 (41.4)	181.7 (36.9)	178.1 (41.5)	191.1 (51.6)
	Neut	200.0 (63.7)	196.9 (43.1)	191.7 (39.2)	193.6 (42.1)	186.0 (44.3)	209.1 (26.8)
Prosaccade	Neg	187.2 (48.2)	192.6 (46.6)	182.2 (35.9)	179.0 (25.7)	180.2 (23.2)	180.5 (23.3)
	Neut	189.4 (48.2)	195.4 (43.7)	185.2 (35.3)	182.8 (27.3)	173.9 (19.2)	180.0 (33.4)

Table 5.3.

Accuracy and eye-movement latencies per trial-type in FA, OM and control groups.

Main effects of inhalation, $F_{(1,49)} = 9.68$, $p = .003$, and trial type, $F_{(1,49)} = 184.28$, $p < .001$, were characterized by a significant trial-type x inhalation interaction, $F_{(1,49)} = 7.00$, $p = .01$. Participants (overall) made significantly greater antisaccade errors during CO_2 inhalation relative to air $t_{(53)} = 3.21$, $p = .002$, but did not differ in prosaccade errors, $t_{(53)} = .517$, $p = .61$.

This interaction was further subsumed by a significant trial-type x inhalation x inhalation order interaction, $F_{(1,49)} = 4.18$, $p = .05$. Post-hoc analysis of separate order-cohorts showed that the trial-type x inhalation interaction was present if the CO_2 was inhaled first, $F_{(1,29)} = 13.47$, $p = .001$, and not if CO_2 inhalation followed air inhalation, $F_{(1,29)} = .132$, $p = .72$. If CO_2 inhalation was first, participants made significantly more errors in the CO_2 inhalation than the air, $t_{(31)} = 4.15$, $p < .001$. If the air inhalation preceded CO_2, there was no difference in scores, $t_{(21)} = .47$, $p = .44$.

There was also a significant inhalation x trial-type x emotion interaction, $F_{(1,49)} = 3.96$, $p = .05$, characterised by a significant inhalation x emotion interaction in antisaccade trials, $F_{(1,51)} = 4.20$, $p = .05$, but not prosaccade trials, $F_{(1,51)} = 2.12$, $p = .15$. In antisaccade trials error rates trended towards being higher for neutral stimuli (relative to negative stimuli) during the CO_2 inhalation, $t_{(53)} = -1.95$, $p = .05$, whilst errors to negative and neutral stimuli were similar during air inhalation, $t_{(53)} = .11$, $p = .91$.

A significant emotion x inhalation order x group interaction, $F_{(1,49)} = 4.78$, $p = .03$, was characterised by an emotion x group interaction if air preceded CO_2, $F_{(1,49)} = 7.16$, $p = .02$, but not if CO_2 preceded air, $F_{(1,49)} = .26$, $p = .78$. Further examination in those who received air first revealed no differences between emotion in either group, *ts* < 1.91, *p*s > .09, and one-way ANOVA revealed no between-group differences across either emotion, *F*s < 1.3, *p*s > .27.

Antisaccade response latencies across group, emotion and trial-type are presented in Table 5.3. In addition to exclusions based on error-rate, 3 further participants were excluded from analysis due to abnormally large response latencies. Correct latencies were examined in a 2 (inhalation: CO_2 vs. air) x 2 (trialtype: antisaccade vs. prosaccade) x 2 (emotion: negative vs. neutral) x 2 (inhalation order: CO_2 first vs. air first) x 3 (group: FA vs. OM vs. relax) ANOVA.

A main effect of emotion, $F_{(1,44)} = 4.78$, $p = .03$, was driven by significantly slower latencies in neutral trials ($M = 190.6$) than negative trials ($M = 185.9$). Exploratory analysis revealed this was only in CO_2 inhalations, $t_{(48)} = 2.11$, $p = .04$, and not air, $t_{(48)} = .93$, $p = .36$, but there was no significant emotion x inhalation interaction.

Non-significant trends were also observed towards main effects of trialtype, $F_{(1,44)} = 3.23$, $p = .08$, with slower latencies in antisaccade vs. prosaccade trials and a trialtype x emotion x group x inhalation order interaction, $F_{(1,44)} = 3.01$, $p = .09$.

Associations between antisaccade performance and self-report measures

Bivariate correlations examined associations between antisaccade error rates during CO_2 and air inhalations and measures of anxiety, mindfulness and attention control using Pearson's *r*, using corrected significance values.

Antisaccade error-rate and dispositional trait measures. There were no associations between antisaccade error rates (in both emotion conditions) during CO_2 or air inhalations, and dispositional trait measures *r*s < .33, *p*s > .02. There were no associations between inhalation error-rate differences (CO_2 vs. air) and trait measures of anxiety, *r*s < -.26, *p*s > .02, and no associations between trait measures and CO_2 vs. air emotion differences (i.e. the difference between emotion-induced errors in the air inhalation and emotion-induced errors in the CO_2 inhalation), *r*s < .19, *p*s > .17.

There was a significant association between STAI scores and emotion-induced prosaccade errors (i.e. difference between errors in negative trials and errors in neutral trials). Higher STAI scores were associated with fewer prosaccade errors during air inhalations, $r = -.49$, $p < .001$.

Antisaccade task latencies and dispositional trait measures. Associations were examined between task latencies during CO_2 and air inhalations, and dispositional trait measures. There were no significant associations between dispositional trait measures and latencies in either inhalation, *r*s < .33, *p*s > .02. There were no associations between dispositional trait measures, and the difference between negative/neutral condition latencies.

Larger CO_2 vs. air latency differences (in neutral trials) were associated with increased FFMQ scores, $r = .44$, $p = .002$.

Antisaccade error-rates and autonomic and self-report measures of anxiety. There were no associations between antisaccade error-rates in either inhalation and autonomic/self-report measures of anxiety. Neutral antisaccade differences were also associated with larger sympathetic-vagal ratio differences, $r = .41$, $p < .001$. Notably, increased air vs. CO_2 SDNN differences were associated with air vs. CO_2 antisaccade latency differences in all 4 antisaccade trial conditions (anti vs. pro, neg vs. neut), *rs* > .41, *p*s < .002.

Discussion

The current study is the first to compare the effect of two components of mindfulness-based attention training (open monitoring and focused attention) with the effects of general relaxation on subjective, autonomic and neuropsychological response to 7.5% CO_2 challenge in healthy volunteers. It was predicted that mindfulness may protect against 7.5% CO_2 inhalation-induced anxiety through i) reduced self-report measures of anxiety and negative affect, particularly in the OM group, ii) reduced autonomic markers of anxiety and iii) reductions in threat-processing biases, particularly in the FA group.

7.5% CO_2 challenge produced significant increases in anxiety and autonomic arousal compared to air inhalation, consistent with previous studies (e.g Bailey et al., 2005; Bailey et al., 2006). However, the effect of CO_2 challenge on self-report anxiety was significantly reduced in those individuals who had completed OM and FA practice, compared to a relaxation control group. The positive effects of acute FA and OM on CO_2-induced anxiety occurred despite participants (irrespective of group) experiencing typical and comparable CO_2-induced increases in autonomic arousal and impaired attention control (as measured by error rates in the antisaccade task). These results extend previous evidence (in Chapter 3) that both FA and OM interventions can increase executive attention. It may be that the reductions in anxiety and negative affect in both FA and OM conditions reflect comparable improvements in top-down attention control that may reduce/protect against anxiety, although further research is needed to determine this relationship given inconclusive findings from the antisaccade task. These results are consistent with experimental findings that mindfulness interventions can reduce anxiety in clinical and subclinical populations (Evans et al., 2008; Goldin & Gross, 2010; Hazlett-Stevens, 2012; Ree & Craigie, 2007).

Mindfulness meditation also led to reduced inhalation-induced negative affect, consistent with evidence from evidence in healthy volunteers (e.g. Brown & Ryan, 2003; Chambers et al., 2007). The observed effect of mindfulness on negative (but not positive) affect is in line with the notion that positive and negative affect are independent and largely disassociated concepts rather than bivalent extremes of a single dimension (Watson et al., 1988). The objective interpretation of internal/external stimuli endorsed by mindfulness is in line with the present finding of a reduction in maladaptive negative affect, but no change in positive affect. The effect of mindfulness on anxiety and negative affect, but not on autonomic measures of anxiety, is consistent with the effects of anxiolytic drugs (e.g. lorazepam; Bailey et al., 2007) on response to CO_2 challenge which reduce subjective feelings of worry and anxiety without impacting heart-rate and blood pressure (see Bailey et al., 2011). Thus it may be that robust physiological effects of 7.5% CO_2 inhalation are ‘downstream’ of pharmacological and mindfulness-based cognitive interventions, and that these interventions are better placed to target the phenomenological experience of CO_2-induced anxiety (i.e. subjective interpretation of persistent internal physiological effects).

It is possible that, in line with current conceptualizations, FA and OM use functionally separate cognitive mechanisms to reduce subjective anxiety. FA practice endorses sustaining attention towards a fixed object (goal-related) and self-monitoring for bottom-up distractors, whereas OM incorporates affective/attitudinal aspects into active monitoring of external/internal perception. Thus, both enable the ‘downplaying’ of autonomic arousal sensations, enabling increased goal- related attention.

The current findings replicate those from previous studies that demonstrate that 7.5% CO_2 challenge increases heart-rate and systolic blood pressure (e.g. Bailey et al., 2005; Cooper et al., 2011; Garner et al., 2012) but not diastolic blood pressure (see Garner et al., 2011). The current study also provides novel evidence that 7.5% CO_2 challenge increases heart-rate variability (SDNN) and decreases sympathetic-vagal balance, consistent with HRV patterns observed in clinically anxious populations (Cohen, Matar, Kaplan, & Kotler, 1999; Licht, de Geus, van Dyck, & Penninx, 2009). This supplementary finding further validates the use of the 7.5% CO_2 challenge as a healthy-volunteer model of generalized anxiety.

CO_2-inhalation caused reduced performance effectiveness (increased antisaccade error-rate; see Ainsworth & Garner, 2013, for a review) in line with cognitive models of anxiety that suggest anxiety causes reductions in cognitive control (Eysenck et al., 2007). In contrast with previous studies (e.g. Garner et al., 2011), CO_2-induced inhalations caused more errors in neutral trials than negative trials. This finding might indicate 'threat-avoidance' reflective of the high level of anxiety this study induced (not seen in previous CO_2 models due to less induced anxiety – Garner et al. reported a CO_2 vs. air state-anxiety effect size of η^2_p = .40 vs. current finding of .68). Notably the order in which participants inhaled CO_2 or air affected antisaccade results, CO_2-induced errors only occurring if participants inhaled CO_2 first. This may reflect subject expectancy – the strong effect of the CO_2 inhalation meaning participants were more relaxed for a subsequent air inhalation (compared to air-first counterparts).

Additionally, there was partial evidence that CO_2-induced anxiety causes hypervigilance to threat (i.e. participants were faster to look to negative stimuli) consistent with previous studies (Garner et al., 2011; Garner et al., 2012) and cognitive-biases associated with anxiety (see Ouimet, Gawronski, & Dozois, 2009 for a review). However there was no effect of CO_2-induced anxiety on performance efficiency (antisaccade latencies) – possible reasons for this could include experimental anxiety common to both inhalations masking any differences in latencies (strong situation: Cooper & Withey, 2009) or limitations of the antisaccade task (Chapter 4).

The present study built on previous research protocols, explicitly examining effects of acute FA/OM practice on attention-to-threat, subjective anxiety and autonomic arousal. While extending evidence that the 7.5% CO_2 challenge is a robust experimental model of anxiety, differences in FA/OM practice could not be determined across the range of outcomes. It may be that OM practice is contingent on functional FA skills, and novice practitioners are unable to solely practice one approach (see Lutz, Slagter, Dunne, & Davidson, 2008). Additionally, further comparison of acute mindfulness interventions with active control conditions (e.g. standard cognitive-behavioural interventions, rather than a passive relaxation control) would enable determination of specific mindfulness-related mechanisms from more general cognitive-therapy related improvements. However, this study is still relevant to examining functional mechanisms of change in mindfulness treatments for naive individuals; previous findings of FA vs. OM differences have predominantly used expert meditators (e.g. Colzato, Ozturk, & Hommel, 2012; Manna et al., 2010). Further examination for conclusive evidence of MBSR/MBCT subcomponents (such as FA and OM) can inform interventions for optimal and efficient treatments of anxiety (e.g. Perlman et al., 2011).

Our finding of comparable effects of FA and OM in reducing subjective anxiety is consistent with earlier finding that acute-sessions of FA and OM have significant and similar increases in executive attention (see Chapter 3), and is consistent with recent suggestions that OM practice involves significant amounts of FA practice, and novice practitioners are unable to perform either method with sufficient specificity to bring out any differential effects (Lutz et al., 2008). However, the present study found no substantial effect of FA/OM on attention-to-threat as indexed by the antisaccade task, in line with (null) findings from Chapter 4. It may be that substantial CO_2-induced changes in task-performance masked more delicate mindfulness-related improvements. Further research is required to determine the extent to which the observed increases in attentional functioning are functionally associated with reduced subjective anxiety. Despite this, investigating OM vs. FA separately is increasingly important as mindfulness-based treatment becomes more prominent: studies using experienced practitioners may be less likely to reflect mechanisms of change that are relevant for MBSR/MBCT treatment protocols.

These findings that mindfulness can protect against inhalation-induced anxiety are consistent with current understanding of how mindfulness could enhance and correct biases in attention control. Further research should clarify the extent to which maladaptive threat-processing is a product of dysfunctional attentional control, and how mindfulness treatments can be used to offer protection against the development of anxiety in healthy individuals. To this end, findings from the four experimental studies in this thesis will be considered in detail in the following chapter.

Chapter 6

General Discussion

Review of thesis aims

Current models of anxiety propose that deficits in cognitive and attention control are risk factors for the development and persistence of worry and anxiety (Eysenck et al., 2007). Dysfunctional attentional control causes maladaptive emotion-processing biases in anxious individuals, that have been reliably demonstrated using behavioural tasks (Bar-Haim et al., 2007). Recently, several cognitive tasks (e.g. ANT, antisaccade task) have demonstrated that anxiety is associated with reduced executive attention (Osinsky, Gebhardt, Alexander, & Hennig, 2012; Pacheco-Unguetti et al., 2010), increased alerting/orienting towards threat (Garner et al., 2012; Pacheco-Unguetti et al., 2010), and reduced cognitive inhibition (Ansari & Derakshan, 2010; Derakshan, et al., 2009; Garner et al., 2011).

Emphasizing deliberate, non-judgmental awareness (of both internal and external stimuli: meta-awareness), mindfulness-based therapies have the potential to aid psychological well-being (Kingston et al., 2007), and affect physiological markers of stress (Grossman et al., 2004). Moreover, mindfulness-based cognitive therapy programs have shown benefits in treating GAD, panic disorder, social phobia and depressive symptoms (summary in Didonna, 2009). Mindfulness-interventions have demonstrated improvements in attentional functioning (Chambers et al., 2007; Jha et al., 2007; Tang et al., 2007) and emotion regulation (Arch & Craske, 2006; Ortner, Kilner, & Zelazo, 2007; see Appendix A). In addition, neurocognitive models of anxiety (e.g. Eysenck et al., 2007; Mogg & Bradley, 1998) are in line with the notion that mindfulness treatments may reduce/protect against anxiety by modulating biased threat-processing. The current thesis reports data from a series of studies in healthy volunteers that systematically examine the effects of mindfulness-meditation practice on attention and emotion-processing biases that characterise anxiety.

Summary of thesis findings

This body of research presented 4 experimental chapters that systematically examined the effects of mindfulness-induced attention control by investigating:

i) the fundamental role of attentional control in the association between dispositional mindfulness, maladaptive internal worrisome thoughts and anxiety;

ii) the effects of two types of mindfulness-based intervention on alerting, orienting and executive control attention mechanisms;

iii) the effects of an integrated mindfulness-based intervention on threat appraisal and attention-to-threat (i.e. emotional regulation typically dysfunctional in anxiety);

iv) the effects of two types of mindfulness-based practice on anxiety, autonomic arousal and threat-processing in an experimental model of anxiety (carbon dioxide challenge).

Study 1 used a cross-sectional self-report design to clarify associations between mindfulness, attention control, worry and anxiety. The findings that the relationship between attention control and worry mediated the relationship between mindfulness and anxiety are in line with cognitive models of dysfunctional attentional control in anxiety. Subsequent experimental studies examined the extent to which mindfulness interventions (FA and OM - see Lutz et al., 2009, and an integrated form) can affect attention network functions of alerting, orienting and executive attention (measured by the Attention Network Task, study 2), cognitive inhibition and attention-to-threat (measured by the antisaccade task, study 3), appraisal of emotional stimuli (measured with the startle probe, study 3) and subjective and autonomic responses to an experimental model of anxiety (7.5% CO_2 challenge, study 4). Study methods and key findings are summarized in Table 6.1.

The findings from these studies are consistent with evidence that mindfulness interventions can improve attention functioning, and the limited evidence that this improvement may reduce maladaptive emotion processing. Beyond specific discussions of findings in previous chapters, the methodical approach adopted can be used to highlight a number of patterns and issues common throughout this thesis. These will be taken in turn, with implications for further research considered.

Table 6.1 Summary of methods and findings.

Study	Participants/Group	Intervention	Self-report findings	Behavioural Findings	Supplementary Findings/comments
1. Mediating role of attention control and worry.	120 healthy student volunteers.	-	Increased dispositional mindfulness (MAAS) associated with decreased anxiety, increased attention control and decreased worry, *r*s > .31, *p*s < .001. Association between mindfulness and anxiety mediated by attention control and worry (CIs ≠ 0)	-	-
2. Effects of FA and OM on attention network function.	*Pre vs. post intervention design.* Focused attention (FA: *N*=24) vs. open monitoring (OM: *N*=25) vs. relaxation control (*N*=24).	8-day intervention with daily homework: Participants attended 3 FA or OM group sessions (approx. length 1-hour) and were asked to complete to a (meditation-type-specific) guided .mp3 practice daily, and immediately before retest.	Interventions did not change self-report mindfulness (MAAS), state/trait anxiety (STAI), attention control (ACS) or worry (PSWQ).	FA and OM both increased executive attention from T1 to T2 (vs. relaxation control, $F_{(2,70)} = 3.32$, $p = .04$. No interaction involving intervention group on ANT measures of alerting or orienting.	Baseline mindfulness (MAAS) positively associated with baseline executive attention (ANT), $r = .25$, $p = .03$.
3. Effects of mindfulness on threat-appraisal and attention-to-threat.	*Pre vs. post intervention design.* Mindfulness (*N*=19) vs. relaxation control (*N* = 20).	5-week intervention. Participants attended 5 weekly group sessions (approx. length 45 minutes). Online delivery of 10-minute guided practice encouraged daily homework practice. Participants also practiced immediately before retest.	Interventions did not change self-report mindfulness (MAAS or KIMS) state/trait anxiety (STAI), attention control (ACS) or worry (PSWQ)	No interaction involving group on antisaccade measures of performance efficiency or effectiveness. No interaction involving group on startle probe fear-potentiation or prepulse inhibition.	Higher baseline mindfulness (MAAS) associated with increased antisaccade error-rate, $r = .53$, $p < .001$, and decreased antisaccade latencies (all trials), $r = .39$, $p = .004$. Increased KIMS score (across time) associated with decreased startle probe amplitude, *r*s > .35, *p*s < .02. Increased mindfulness (MAAS) score (across time) associated with decreased startle fear-potentiation, *r*s > .33, *p*s < .04.
4. Effects of FA and OM on 7.5% CO_2-challenge.	*In-session practice design.* FA (*N*=26) vs. OM (*N*=23) vs. relaxation control (*N*=11).	In-session practice. Participants completed 10-minute guided FA or OM practise before completing 7.5% CO_2-challenge.	FA and OM practice reduced CO_2-induced anxiety (SSAI,) and negative affect ($PANAS_{negative}$) vs. healthy controls, F*s* > *2.6, p*s < .07. CO_2-inhalation caused increased anxiety (SSAI), negative affect ($PANAS_{negative}$) and decreased positive affect, *F*s > 24.9, *p*s < .001.	CO_2 inhalation increased autonomic arousal measures (HR, SBP, DBP, HRV) vs. air, *Fs* > 3.42, *p*s .07, but there was no interaction involving group on autonomic arousal. CO_2 inhalation increased antisaccade errors (vs. air), $F_{(1,49)} = 9.68$, $p = .003$, but this did not interact with mindfulness group.	CO_2-inhalation caused 'threat-avoidance' antisaccade pattern (participants found it easier to orient away from threat relative to neutral images on antisaccade trials), $F_{(1,49)} = 3.96$, $p = .05$.

Associations between dispositional mindfulness, anxiety, attention and threat-processing in the normal population.

In line with previous findings (e.g. Walsh et al., 2009; Fisak & Lehe, 2011), self-report measures consistently demonstrated that increased dispositional mindfulness is associated with decreased anxiety, increased attentional control and decreased worrying thoughts. Importantly, findings from study 1 indicated that the roles of attentional control and worry are fundamental to the association between increased dispositional mindfulness and reduced anxiety. Subsequent evidence that dispositional mindfulness is related to increased executive attention (indexed by the ANT) and improved processing efficiency regarding attention-to-threat (findings from antisaccade task) are consistent with suggestions that mindfulness reduces anxiety through the modulation of maladaptive threat biases.

Dispositional mindfulness was measured using several inter-correlated scales throughout the thesis: the MAAS (Brown & Ryan, 2003), KIMS (Baer, Smith, & Allen, 2004) and FFMQ (Baer et al., 2008). Mindfulness measures (i.e. KIMS and FFMQ) that incorporate attitudinal/compassionate aspects of mindfulness were incorporated to address concerns that ‘mindful attention’ as indexed by the MAAS was inherently similar to attentional control (i.e. ACS), although correlational findings suggest the two are separate constructs and share less than 25% common variance (rs < .5).

Recent debate has, however, questioned the legitimacy of i) attempting to operationalize the multiple facets of mindfulness, and ii) focusing research towards one facet [attention], potentially jeopardizing ecological validity and research application (Grossman, 2011). However, this thesis maintained a stringent focus on ‘sati-related’ attentional mechanisms involved in the hypothesized benefits of mindfulness practice. This enabled experimental designs that provide relevant contributions in identifying functional ‘pathways of impact’ for mindfulness practice, without engaging in detailed debate as to the construct of mindfulness itself (see Brown et al., 2011).

Evaluating mindfulness interventions in experimental settings.

The mindfulness interventions used in the experimental studies were designed/performed by a highly experienced practitioner/teacher (Level 5/6, Crane et al. 2012). Despite this, and the changes in behavioural tasks, self-report scores on measures of dispositional mindfulness did not significantly change between pre and post-test sessions. It is possible that the mindfulness self-report scales used may index inherently stable mindfulness constructs, or the scales may be insufficiently sensitive to change. Notably, of 18 longitudinal examinations of mindfulness interventions in healthy volunteers examined in Table 1.1, only 5 reported significant increases in self-report dispositional mindfulness measures. In developing /refining mindfulness interventions (for both clinical and experimental use) it is important to consider the extent to which changes in dispositional mindfulness actually relate to improvements in attention (and anxiety). Acute mindfulness *practice,* outside of dispositional changes, may effect improvements in attention that translate to reduced anxiety. Further research should determine the efficacy with which interventions induce long-term changes in mindfulness (including mindful behaviour) and the extent to which current self-report measures are appropriate to index such changes.

Furthermore, two experimental studies (Chapters 3 and 4) within the thesis did not demonstrate changes in self-report measures of anxiety or attention, in contrast with evidence from cognitive measures and observed changes from Chapter 5. It may be that the efficacy of short-term mindfulness interventions in reducing trait anxiety is limited - particularly given the robust nature of both dispositional mindfulness *and* trait anxiety. Additionally, the Spielberger Trait Anxiety Inventory (STAI) may measure anxiety that is stable over time (Spielberger & Sydeman, 1994). In contrast to items on the STAI, which refer primarily to an individual's nature (e.g. "I wish I was as happy as others seem to be"; see Appendix 11), alternative anxiety measures such as the Generalized Anxiety Disorder 7-item (GAD-7; Spitzer, Kroenke, Williams & Lowe, 2006) focus on individual experience over previous weeks (e.g. "Over the last two weeks, how often have you been bothered by the following problems: Not being able to stop or control worrying?"). Such measures may detect changes in anxiety that are overlooked by the more resistant-to-change STAI.

Furthermore, it is possible that the impact of any mindfulness intervention is limited towards anxiety measures in healthy volunteers (consistent with observed anxiety reductions in the 7.5% CO_2 experimental model of anxiety). Normal individuals may have sufficiently high attentional control/low anxiety which is unlikely to be furthered by mindfulness meditation. Indeed, current examinations of the impact of mindfulness interventions on anxiety measures have used primarily clinical/sub-clinical populations, with little evidence for effects in healthy volunteers (Grossman et al., 2004; Vollestad et al., 2012; Khoury et al., 2013). Cognitive measures such as the ANT and the antisaccade task may therefore index attentional changes in healthy individuals that reflect more substantial changes in trait anxiety in anxious individuals.

In contrast to potentially insensitive measures of trait anxiety and mindfulness, there was no effect of mindfulness meditation on measures of state anxiety or worry in Chapters 3 and 4. Given that mindfulness meditation reduced state anxiety induced through CO_2 inhalation, it may be that experimental conditions produced uniform worry/state-anxiety responses in healthy individuals that masked any effects of mindfulness meditation (see strong situation; Lissek et al. 2006).

The interventions used in this body of research consisted of acute schedules, incorporating guided sessions and brief daily practises. While acute interventions (e.g. Chambers et al., 2008; Moore et al., 2012; Tang et al., 2007) are experimentally pragmatic (i.e. easy recruitment, reduced dropout/increased experimental power), the brief nature may have contributed to lack of self-report changes. Whereas longer MBSR/MBCT courses introduce general mindfulness-related concepts (such as FA and OM) to individuals and allow the development of personal/individual methods and techniques, our experiment was designed to investigate the impact of specific mindfulness-related concepts (i.e. attention). To that end, group sessions (with instructed-practice and discussion) informed and explained mindfulness techniques, which were than activated in-session – thus allowing comparison of component processes of mindfulness and attention. Some consideration must be given to population characteristics throughout the thesis. Whilst a naive, healthy young adult sample is reflective of the naive populations that typically begin MBSR programmes, participants may not have adhered to practice schedules with the same rigour as those seeking treatment for anxiety disorders. Although this issue was addressed with the introduction of practice monitoring (study 3), recent evidence suggests that practice quality (vs. quantity) is a relevant factor in positive outcomes (Del Re, Flückiger, Goldberg, & Hoyt, 2013). Further research should consider whether short mindfulness programmes can achieve the high-quality practices associated with the phenomenological experience of ‘mindfulness’ typical of extensive practice, using measures such as the Practice Quality – Mindfulness self-report measure (PQM: Del Re et al., 2013). The PQM operationalizes ‘mindfulness’ as the maintenance of balanced perseverance/resolve during formal mindfulness practice.

The current evaluation of mindfulness practices/interventions did not involve an active control group. FA/OM practice induced selective change in both experimental ANT measures (executive attention but not alerting/orienting/global RTs) and subjective responses to CO_2 inhalation (anxiety and negative affect but not positive affect or autonomic arousal). These findings indicate genuine effects of FA and OM on attention and anxiety, rather than demand characteristics that might follow short-term practice and induction. That said, future work should build on these findings by employing active control interventions that go beyond the test-retest/relaxation control groups that have been typically used to date (e.g. 11 of 15 prospective or randomized controlled trials reviewed by Chiesa et al. (2011) used wait-list/no practice control groups). It remains a challenge to develop appropriate control conditions for mindfulness research – however, recent innovative and comprehensive blinding procedures offer promise (e.g. Health Enhancement Plan; MacCoon et al., 2012). Such controls will help reduce participant demand characteristics that otherwise impede the assessment of mindfulness mechanisms. The inclusion of treatment fidelity measures (particularly regarding FA/OM specificity) would also help clarify the specific mechanisms responsible for change, in line with calls for increasingly rigorous conduct and evaluation of intervention research (Bellg et al., 2004).

Evaluating the use of experimental paradigms to measure the impact of mindfulness on specific aspects of cognition and emotion.

Current (neuro)cognitive conceptualizations of anxiety commonly emphasize the importance of biased top-down/bottom-up models of attention in anxious individuals (Eysenck et al., 2007; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998). Biases in threat-appraisal and selective attention-to-threat have been reliably demonstrated in behavioural tasks (see Bar-Haim et al., 2007; Ainsworth & Garner, 2013 for a review) and are consistent with neuroimaging evidence of dysfunctional prefrontal regulation of amygdalic threat-processing regions in anxiety (Bishop, 2007). Thus, the body of work in this thesis is strictly focused on the impact of mindfulness meditation on attentional control, and implications that increases in attentional control might have for maladaptive threat-processing in anxiety.

In keeping with examining specific attention/threat-processing components, the emotional-variant of the Attention Network Test (ANT; Fan et al., 2002) examined attention network function in alerting, orienting and executive attention (resolving stimuli conflicts), providing robust measures of attentional control in a task with good test-rest reliability (Fan et al., 2002). Building on this, subsequent research within the thesis used two robust measures of threat-processing: threat-appraisal was measured using the startle-probe (Vrana et al., 1988) and attention-to-threat was measured using the antisaccade task (Ainsworth & Garner, 2013). Evaluations of psychological and pharmacological interventions on dysfunctional cognition/emotion-processing in anxiety have used a range of i) measures of attentional bias, such as the visual probe task (Brosan et al., 2011; Browning, Reid, Cowen, Goodwin, & Harmer, 2007) or dichotic listening tasks (Hayes, Hirsch, Krebs, et al., 2010; Lutz et al., 2009) and ii) measures of emotion processing, such as facial expression recognition paradigms (Reinecke, Cooper, Favaron, Massey-Chase, & Harmer, 2011) and the emotional Stroop (Munafò, Hayward, & Harmer, 2006). Notably, the majority of these studies rely solely on post-intervention between-group comparisons and do not include pre-intervention test sessions that would otherwise quantify intervention-induced *change* in performance. Thus, a strength of this thesis is the inclusion of baseline testing and pre-post comparisons that quantify within-subject change, and individual differences in *response* to intervention.

Future research must comprehensively relate the extent to which mindfulness-related attentional improvement is responsible for improvements in anxiety, beyond cross-sectional observations of mediating relationships recommended by Kuyken et al., 2010 (i.e. Chapter 2). Despite several challenges, such as the robust nature of dispositional anxiety and mindfulness in healthy volunteers, new experimental methods are increasingly available. Neuroimaging techniques may be able to determine the degree to which mindfulness-related attentional improvements can relate to functional changes in neurocognitive models of anxiety and threat-processing.

Recent research has noted the potential confounds that may compromise the use of cognitive tasks alongside mindfulness interventions, not least regarding ‘attentional effort’ (see Jensen et al., 2012). The findings from study 3 (namely that *dispositional* mindfulness appears to be associated with increased performance efficiency, but decreased performance effectiveness) appear to support this notion. Care must be taken to ensure changes in task performance accurately reflect proposed changes in cognitive mechanisms, potentially through the use of convergent behavioural paradigms. Existing pharmacological interventions have associated changes in emotion-processing with reduced amygdalic activity (e.g. Murphy, Norbury, O’Sullivan, Cowen, & Harmer, 2009) and increased prefrontal downregulation (e.g. Norbury, Mackay, Cowen, Goodwin, & Harmer, 2008). Consistent with predictions generated by neurocognitive anxiety models (Bishop, 2007) similar observations in mindfulness-based interventions would help clarify their implications for emotion-processing.

There are several experimental models that have effectively induced anxiety in healthy populations, for example simulated public speaking or conditioned response models (Graeff et al., 2001). However, the 7.5% CO_2-challenge has reliably induced changes in subjective anxiety and negative affect (Poma et al., 2005) increased hypervigilance (Garner et al., 2012) and biased emotion-processing (Cooper et al., 2011; Garner et al., 2011) and this paradigm seems well placed to model GAD characteristics in healthy volunteer studies of therapeutic interventions such as mindfulness meditation. Despite this, further research is needed to translate promising findings (both within this thesis, and mindfulness-based research at large) into groups of patients with GAD.

Implications and Impact

Although reductionist at times (therefore perhaps limiting any findings' relevance to acceptance-based mindfulness approaches), the rigorous experimental testing of component processes presented in this thesis is necessary to improve outcomes in anxiety-based research, and in line with contemporary demands for evidence-based psychological interventions (Nichols et al., 2007; Spring, 2007). Refined group-based interventions – such as mindfulness meditation – are particularly relevant for conditions like anxiety disorders which are both costly and often difficult to treat. It is important that well-designed research continues to inform such interventions as they become increasingly popular in clinical settings.

As a whole, this thesis presents evidence that two types of mindfulness (FA and OM) can improve attentional control, which was shown to be an important factor in the association between mindfulness and anxiety. Furthermore, use of a novel experimental model demonstrated that FA/OM can modulate subjective anxiety and negative affect, with limited evidence that this improvement may reduce anxiety through effects in threat-processing. Findings from the thesis are relevant to research that aims to improve/refine existing mindfulness-based treatments, and identify specific individuals who may benefit from them.

Appendices

Appendix A

Table 1.1. Effects of mindfulness interventions on experimental measures of attention and emotion regulation.

Author	Participants and Comparison	Intervention	Task/Measure	Findings	Notes/additional findings.
			Mindfulness and Attention		
Anderson et al. (2007).	*Pre vs. post intervention design.* Healthy naïve adult intervention group (*N* = 39) vs. wait-list control (WLC; *N* = 33).	8-week MBSR course	Vigil Continuous Performance Test (switch task); Object detection task; Stroop task.	Mindfulness group had improved performance on switch task (vs. WLC) No effect of group on stroop or object detection.	Intervention increased scores on Toronto Mindfulness scale (vs WLC).
Brefczynski-Lewis et al. (2007).	Long-term Buddhist meditators (*N*=14) vs. incentivised novice-meditators (*N* = 10) vs. age-matched healthy non-meditators (*N* = 16).	n/a	'One-point meditation' performed during fMRI, with distracting sounds.	All groups demonstrated increased activation in attention regions during meditation. EMs (vs. novices) had less activation in regions related to discursive thoughts and emotions.	Experienced meditators (~19,000hrs) had more brain activation in attention regions (vs. novice controls) while very experienced meditators (44,000hrs) had less.
Campbell et al. (2012).	*Pre vs. post intervention design.* Female cancer patients, intervention (*N*=45) vs. WLC (*N* = 31), median split into high vs. low blood pressure (BP)	8-week MBSR course	Resting blood-pressure Questionnaire measures of rumination and mindfulness (MAAS)	Mindfulness group increased in MAAS scores and decreased rumination (vs. WLC). Mindfulness/high BP ppnts (according to median splits) had decreased BP after intervention (vs. WLC).	Mindfulness/low BP ppnts had increased BP after MBSR, suggesting normalization over time.
Carter et al. (2005).	23 Buddhist monks in two types of meditation: compassion/acceptance vs. 'one point mediation'	n/a	Binocular rivalry/visual switching task.	One-point meditation caused increase in attention stabilization vs. compassion group.	Monks were own controls (relied on verbal self-report)
Chambers et al. (2008)	*Pre vs. post intervention design.* Healthy adult intervention group (*N*=20) vs. WLC (*N*=20).	10-day intensive meditation course	Digit Span Backward scale. Internal Switching Task (IST)	Mindfulness improved at digit span task (vs. WLC). Mindfulness group improved at IST while WLC did not.	-
Crane et al. (2012)	*Pre vs. post intervention design.* Depressed w/ history of suicidality, intervention group (*N*=14) vs. TAU (*N*=13).	Full MBCT treatment (approx. 3-4 months)	Structured clinical interview, including Autobiographical Memory Test and Measure to Elicit Positive Future Goals and Plans.	Mindfulness group had improvement on specificity of life goals (vs TAU group).	-
Ekblad (2009).	*Pre vs. post intervention design.* Healthy adult volunteers (*N*=56) randomly assigned to intervention group or WLC.	8-week MBSR course.	Mindful monitor task (MM) Paced Auditory Serial Addition Task (PASAT).	No between group differences in measures of attention.	-
Farb et al. (2013).	Healthy intervention group (*N*=20) vs. WLC (*N=16).*	8-week MBSR course.	fMRI during tasks measuring interoceptive and exteroceptive attention.	Mindfulness group had increased functional plasticity in areas associated with 'present-moment awareness' during interoceptive attention (vs. WLC).	No pre-intervention measure (only post-intervention).
Jha et al. (2007).	*Pre vs. post intervention design.* Student intervention group (*N*=17) vs. expert meditator retreat group (*N*=17) vs. no-intervention controls (*N*=17).	8-week MBSR course.	Attention network test (ANT)	Pre-test, retreat group had better executive attention (vs MBSR and controls) Post-test, MBSR had improved orienting (vs. retreat and controls), no group differences in executive attention.	At T2 retreat group demonstrated improved alerting to exogenous stimuli (vs. MBSR and controls) but no overall improvement.
Lutz et al. (2009). & Slagter et al. (2007)	*Pre vs. post intervention design,* Experienced practitioner intervention group (*N*=17) vs. WLCs (*N*=23).	3-month intensive meditation course in Vipassana meditation.	Dichotic listening task (DLT: Lutz et al); Attention Blink Task (ABT: Slagter et al) and EEG.	Both groups improved DLT performancer at T2 but mindfulness group had reduced response variability. Mindfulness group had improved ABT performance at T2.	In DLT those who had greatest response variability reduction also showed greatest reduction in neural processing.
Lykins et al. (2012).	Experienced meditators (av. 6 years, *N*=33) vs. demographically matched non-meditators (*N*=33).	n/a	Continuous Performance Task (vigilance task); Selective Attention Test; Emotional Stroop; (& other measures)	Group differences were non-significant for all attentional tasks.	Mindfulness group were better (vs. controls) at short-term and long-term memory recall tasks.

Moore et al. (2012).	*Pre vs. post intervention design,* Healthy participants intervention group (*N*=12) vs WLC (*N*=16).	3-hours training (2 hours before T1 testing), with 'homework' of 10min/per day.	ERP analysis of Colour-Stroop task.	No differences at T1 (i.e. 2 hours of practice). Behavioural measures did not change between groups, but increased N2/ decreased P3 components in mindfulness group (vs. controls).	N2 increases and P3 decreases associated with increased inhibition/attention control.
Moore & Malinowski (2009).	Experienced meditators, at least intermediate standard (*N*=25) vs. naïve non-meditators (*N*=25).	n/a	Stroop interference task; d2-concentration and endurance test.	Mindfulness group were better at stroop task and d2 concentration task.	Self-report measures of mindfulness were correlated with behavioral attention measures.
Polak (2009).	Novice meditators (*N*=150) randomly assigned to mindfulness, relaxation or neutral training groups.	15-minute training task (mindful vs. relax vs. neutral).	ANT; Stroop interference task.	Mindfulness group was better at alerting than relax group, but no different to the control group.	Two task sessions (2 days apart, training session before both tasks).
Semple (2010).	*Pre vs. post intervention design.* Mindfulness intervention (MM: *N*=15) vs. progressive muscle relaxation (PMR:*N*=14*)* vs. WLC (*N*=16*)*.	MM & PMR: 90-minutes training & 1-month of twice-daily home practice.	Continuous performance test; Stroop interference task.	All groups improved similarly (and significantly) at Stroop. Mindfulness group improved at CPT discrimination compared to PMR and WLC.	-
Tang et al. (2007).	*Pre vs. post intervention design.* Chinese undergraduate intervention group (*N*=40) vs. control group (*N* = 40).	5-day 20-min per day of integrative body-mind training (IBMT)	ANT; salivary cortisol after stressor (mental arithmetic)	Mindfulness group had improved executive attention on ANT (vs. controls) and reduced stress-related cortisol (vs. controls).	-
Teper & Inzlicht (2013)	Meditators (at least 1 year experience [*M* = 3.2 years], *N* = 20) vs. non-meditator controls (*N* = 18).	n/a	Stroop interference task during EEG recording.	Meditators made fewer stroop errors [trend] and had higher ERN (error-related negativity) than controls.	Higher ERN typically associated with increased brain-based performance monitoring.
van den Hurk et al. (2010a) & van den Hurk et al. (2010b).	Experienced mindfulness meditators (MM: *N*=20) vs. healthy age/gender matched controls (*N*=20)	n/a	ANT; choice reaction time task (CRTT)	MM had better orienting and executive attention scores in ANT, and showed reduced effect of visual distractors on CRTT (vs. controls).	-
van Vugt & Jha (2011)	*Pre vs. post intervention design.* Experienced meditators (av. 1800hrs, *N* = 29) vs. age/gender matched controls (*N* = 29).	1-month intensive retreat aimed at concentrative/ receptive attention (11h daily)	Delayed-recognition task with face stimuli.	Accuracy did not differ between groups at either time point. Mindfulness group were faster and less variable at time 2 (vs. control group).	-
Zeidan et al. (2010).	*Pre vs. post intervention design.* Brief meditation training (*N*=24) vs. matched active control (*N* = 25).	MM: four 20-min practices; Control: four 20-min book readings (over 4 days).	N-back task, Symbol Digit Modalities task (SDM); verbal fluency task.	MM improved SDM, N-back hit runs and verbal fluency performance (vs. controls). N-back speed was not affected.	-

Mindfulness and Emotion Processing

Arch & Craske (2006).	Healthy undergraduates (*N*=60) randomized to 15-min induction training.	Focused breathing 'induction' vs. unfocused attention induction vs. worrying thoughts induction.	Affect rating of positive, neutral and negative IAPS pictures.	Focused breathing group rated neutral slides as significantly more positive after induction (vs. worry and unfocused attention who responded negatively at T2).	Focused breathing group also reported reduced negative affect (vs. unfocused attention and worry).
Britton et al. (2012).	*Pre vs. post intervention design.* MDD sufferers in partial remission, mindfulness intervention (*N*=26) vs. WLC (*N*=19).	8-week MBCT course.	STAI-Y (emotional reactivity to stress)	MBCT had reduced STAI-Y scores (vs. WLCs) at T2.	-
Desbordes et al. (2012).	*Pre vs. post intervention design,* Healthy adults (*N*=52) randomized to two interventions vs. active control.	8-week Mindful Attention Training (MAT) vs. 8-week Cognitively-based compassion training vs. 8-week health discussion course.	Presentation of positive, negative & neutral IAPS pictures during fMRI.	MAT group had decrease amygdala activation to positive images, and emotional images overall (vs. CBCT & controls). CBCT had trend increase in amygdala response to negative pictures (vs. MAT & controls).	CBCT increased amygdalic activation correlated with decrease in BDI depression scores.
Dickenson et al. (2013).	Healthy adults in smoking cessation program (*N*=31).	Focused breathing 'induction' vs. unfocused attention induction.	Participants completed both inductions while fMRI occurred.	FB had increased activation in fronto-parietal regions involved in attention control (vs. MW), & MW had increased pre-frontal activation associated with default mode network (vs. FB).	-
Ekblad (2009).	*Pre vs. post intervention design.* Healthy adult volunteers (*N*=56) randomly assigned to intervention group or WLC.	8-week MBSR course.	Mindful monitor task (MM) Paced Auditory Serial Addition Task (PASAT).	No between group differences in measures of emotion regulation.	Self-report measures suggest training led to decreased negative emotional experience following a stressor.

Glück & Maercker (2011).	*Pre vs. post intervention design.* Healthy adult intervention group (*N*=28) vs. WLC (*N* = 21).	Online mindfulness-based training, 13-days of 20-mins per day.	Self-report measures of mindfulness (FMI), Positive and Negative Affect (PANAS) and perceived stress.	Trends that intervention reduced self-report stress and negative affect, but non-significant increase in mindfulness.	Significant effects in participants who participated over 50% of the time.
Jha et al., (2010).	*Pre vs. post intervention design.* Two military cohorts during high-stress predeployment period, randomized to intervention group (*N*=31) vs. control (*N*=17). Interventions were median split according to reported mindfulness practice (high vs. low).	8-week Mindfulness-based fitness training (MMFT).	Opsan task (indexes working memory) & PANAS scale.	High-practice MMFT group had improved working memory scores at T2, reduced negative affect and increased positive affect (vs. MMFT low practice and controls).	Relationship between practice time and negative (not positive) affect was mediated by working memory capacity.
Ortner et al. (2007) [Study 2]	*Pre vs. post intervention design.* Healthy adults randomized to two intervention groups (*N*s=21,23) vs. WLC (*N*=24).	7-week mindfulness meditation (MM) vs. 7-week relaxation meditation (RM) vs. WLC.	Emotional interference task (EIT) & Picture rating task (using IAPS images)	MM lead to reduced interference from negative pictures on EIT, and reduced reported valence of negative pictures (vs. RM & WLC).	MM also increased on self-report measures of mindfulness, RM and MM increased on self-report measures of vitality & self-compassion.
De Raedt et al. (2011).	*Pre vs. post intervention design.* Adults with history of MDD intervention group (*N=45)* vs. non-treatment seeking adults with MDD history (*N*=26).	8-week MBCT course	Negative affective priming task (NAP; emotional visual probe)	At T1, MBCT group showed inhibition to positive emotional stimuli and facilitation of attention to negative stimuli (vs. controls). At T2 facilitation of negative and inhibition of positive were reduced (vs. T1 scores).	MCBT group increased in MAAS and BDI scores (vs. controls and T1 scores).

Abbreviations: STAI = State-Trait Anxiety Inventory (Spielberger et al., 1983), BDI = Beck Depression Inventory (Beck et al., 1996), MAAS = Mindful Attention Awareness Scale (Brown & Ryan, 2004), FMI = Frieberg Mindfulness Inventory (Walach, Buchheld, Buttenmüller, Kleinknecht, & Schmidt, 2006), MDD = Major Depressive Disorder, TAU = treatment as usual.

Appendix B

Mindful Attention Awareness Scale

Instructions: Below is a collection of statements about your everyday experience. Using the 1-6 scale below, please indicate how frequently or infrequently you currently have each experience. Please answer according to what really reflects your experience rather than what you think your experience should be.

1	2	3	4	5	6
Almost Always	Very frequently	Somewhat Frequently	Somewhat Infrequently	Very Infrequently	Almost Never

I could be experiencing some emotion and not be conscious of it until some time later.	1	2	3	4	5	6
I break or spill things because of carelessness, not paying attention, or thinking of something else.	1	2	3	4	5	6
I find it difficult to stay focused on what's happening in the present.	1	2	3	4	5	6
I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.	1	2	3	4	5	6
I tend not to notice feelings of physical tension or discomfort until they really grab my attention.	1	2	3	4	5	6
I forget a person's name almost as soon as I've been told it for the first time.	1	2	3	4	5	6
It seems I am "running on automatic," without much awareness of what I'm doing.	1	2	3	4	5	6
I rush through activities without being really attentive to them.	1	2	3	4	5	6
I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.	1	2	3	4	5	6
I do jobs or tasks automatically, without being aware of what I'm doing.	1	2	3	4	5	6
I find myself listening to someone with one ear, doing something else at the same time.	1	2	3	4	5	6
I drive places on "automatic pilot" and then wonder why I went there.	1	2	3	4	5	6
I find myself preoccupied with the future or the past.	1	2	3	4	5	6
I find myself doing things without paying attention.	1	2	3	4	5	6
I snack without being aware that I'm eating.	1	2	3	4	5	6

Appendix C

Attention Control Scale

Please rate each of these items on a scale of 1 (almost never) to 4 (always).
1=almost never; 2=sometimes; 3=often; 4=always

1.	It's very hard for me to concentrate on a difficult task when there are noises around.	1	2	3	4
2.	When I need to concentrate and solve a problem, I have trouble focusing my attention.	1	2	3	4
3.	When I am working hard on something, I still get distracted by events around me.	1	2	3	4
4.	My concentration is good even if there is music in the room around me.	1	2	3	4
5.	When concentrating, I can focus my attention so that I become unaware of what's going on in the room around me.	1	2	3	4
6.	When I am reading or studying, I am easily distracted if there are people talking in the same room.	1	2	3	4
7.	When trying to focus my attention on something, I have difficulty blocking out distracting thoughts.	1	2	3	4
8.	I have a hard time concentrating when I am excited about something.	1	2	3	4
9.	When concentrating I ignore feelings of hunger or thirst.	1	2	3	4
10.	I can quickly switch from one task to another.	1	2	3	4
11.	It takes me a while to get really involved in a new task.	1	2	3	4
12.	It is difficult for me to coordinate my attention between the listening and writing required when taking notes during lectures.	1	2	3	4
13.	I can become interested in a new topic very quickly.	1	2	3	4
14.	It is easy for me to read or write while I'm also talking on the phone.	1	2	3	4
15.	I have trouble carrying on two conversations at once.	1	2	3	4
16.	I have a hard time coming up with new ideas quickly.	1	2	3	4
17.	After being interrupted or distracted, I can easily shift my attention back to what I was doing before.	1	2	3	4
18.	When a distracting thought comes to mind, it is easy for me to shift my attention away from it.	1	2	3	4
19.	It is easy for me to alternate between two different tasks	1	2	3	4
20.	It is hard for me to break from one way of thinking about something and look at it from another point of view.	1	2	3	4

Appendix D

Penn-State Worry Questionnaire

Rate each of the following statements on a scale of 1 ("not at all typical of me") to ("very typical of me"). Please do not leave any items blank.

Not at all typical of me				Very typical of me
1	2	3	4	5

1.	If I do not have enough time to do everything, I do not worry about it.	1	2	3	4	5
2.	My worries overwhelm me.	1	2	3	4	5
3.	I do not tend to worry about things.	1	2	3	4	5
4.	Many situations make me worry.	1	2	3	4	5
5.	I know I should not worry about things, but I just cannot help it.	1	2	3	4	5
6.	When I am under pressure I worry a lot.	1	2	3	4	5
7.	I am always worrying about something	1	2	3	4	5
8.	I find it easy to dismiss worrisome thoughts.	1	2	3	4	5
9.	As soon as I finish one task, I start to worry about everything else I have to do.	1	2	3	4	5
10.	I never worry about anything.	1	2	3	4	5
11.	When there is nothing more I can do about a concern, I do not worry about it any more.	1	2	3	4	5
12.	I have been a worrier all my life.	1	2	3	4	5
13.	I notice that I have been worrying about things.	1	2	3	4	5
14.	Once I start worrying, I cannot stop.	1	2	3	4	5
15.	I worry all the time.	1	2	3	4	5
16.	I worry about projects until they are done.	1	2	3	4	5

Appendix E

Spielberger State-Trait Anxiety Inventory (Trait)

INSTRUCTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and circle the appropriate number to the right of the statement to indicate how you **generally** feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

		Not at all	Somewhat	Moderately	Very much so
1)	I feel pleasant..	1	2	3	4
2)	I feel nervous & restless...................................	1	2	3	4
3)	I feel satisfied with myself...............................	1	2	3	4
4)	I wish I could be as happy as others seem to be...	1	2	3	4
5)	I feel like a failure	1	2	3	4
6)	I feel rested.............................……………….	1	2	3	4
7)	I am 'calm, cool and collected'..........................	1	2	3	4
8)	I feel that difficulties are piling up so that I cannot overcome them.....................................	1	2	3	4
9)	I worry too much over something that doesn't really matter...	1	2	3	4
10)	I am happy..	1	2	3	4
11)	I have disturbing thoughts...............................	1	2	3	4
12)	I lack self-confidence.......................................	1	2	3	4
13)	I feel secure..	1	2	3	4
14)	I make decisions easily..................................	1	2	3	4
15)	I feel inadequate...	1	2	3	4
16)	I am content..	1	2	3	4
17)	Some unimportant thought runs through my mind and bothers me.......................................	1	2	3	4
18)	I take disappointments so keenly that I can't put them out of my mind......................................	1	2	3	4
19)	I am a steady person......................................	1	2	3	4
20)	I get in a state of tension or turmoil as I think over my recent concerns and interests………..	1	2	3	4

Appendix F

Spielberger State-Trait Anxiety Inventory (state)

INSTRUCTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and circle the appropriate number to the right of the statement to indicate how you feel **RIGHT NOW**. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

		Not at all	Somewhat	Moderately so	Very much so
1)	I feel calm	1	2	3	4
2)	I feel secure	*1*	2	3	4
3)	I am tense	1	2	3	4
4)	I feel strained	1	2	3	4
5)	I feel at	1	2	3	4
6)	I feel upset	1	2	3	4
7)	I am presently worrying over possible misfortunes.	1	2	3	4
8)	I feel satisfied	1	2	3	4
9)	I feel frightened	1	2	3	4
10)	I feel comfortable	1	2	3	4
11)	I feel self-confident	1	2	3	4
12)	I feel nervous	1	2	3	4
13)	I am jittery	1	2	3	4
14)	I feel indecisive	1	2	3	4
15)	I am relaxed	1	2	3	4
16)	I feel content	1	2	3	4
17)	I am worried	1	2	3	4
18)	I feel confused	1	2	3	4
19)	I feel steady	1	2	3	4
20)	I feel pleasant	1	2	3	4

Appendix G

Kentucky Inventory of Mindfulness Skills

Please rate each of the following statements using the scale provided. Write the number in the blank that best describes your own opinion of what is generally true for you.

1	2	3	4	5
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

	1	I notice changes in my body, such as whether my breathing slows down or speeds up.
	2	I'm good at finding words to describe my feelings.
	3	When I do things, my mind wanders off and I'm easily distracted.
	4	I criticise myself for having irrational or inappropriate emotions.
	5	I pay attention to whether my muscles are tense or relaxed.
	6	I can easily put my beliefs, opinions, and expectations into words.
	7	When I'm doing something, I'm only focused on what I'm doing, nothing else.
	8	I tend to evaluate whether my perceptions are right or wrong.
	9	When I'm walking, I deliberately notice the sensations of my body moving.
	10	I'm good at thinking of words to express my perceptions, such as how things taste, smell, or sound.
	11	I drive on "automatic pilot" without paying attention to what I'm doing
	12	I tell myself that I shouldn't be feeling the way I'm feeling.
	13	When I take a shower or bath, I stay alert to the sensations of water on my body.
	14	It's hard for me to find the words to describe what I'm thinking.
	15	When I'm reading, I focus all my attention on what I'm reading.
	16	I believe some of my thoughts are abnormal or bad and I shouldn't think that way.
	17	I notice how foods and drinks affect my thoughts, bodily sensations, and emotions.
	18	I have trouble thinking of the right words to express how I feel about things.

	19	When I do things, I get totally wrapped up in them and don't think about anything else.
	20	I make judgments about whether my thoughts are good or bad.
	21	I pay attention to sensations, such as the wind in my hair or sun on my face.
	22	When I have a sensation in my body, it's difficult for me to describe it because I can't find the right words.
	23	I don't pay attention to what I'm doing because I'm daydreaming, worrying, or otherwise distracted.
	24	I tend to make judgments about how worthwhile or worthless my experiences are.
	25	I pay attention to sounds, such as clocks ticking, birds chirping, or cars passing.
	26	Even when I'm feeling terribly upset, I can find a way to put it into words.
	27	When I'm doing chores, such as cleaning or laundry, I tend to daydream or think of other things.
	28	I tell myself that I shouldn't be thinking the way I'm thinking.
	29	I notice the smells and aromas of things.
	30	I intentionally stay aware of my feelings.
	31	I tend to do several things at once rather than focusing on one thing at a time.
	32	I think some of my emotions are bad or inappropriate and I shouldn't feel them.
	33	I notice visual elements in art or nature, such as colors, shapes, textures, or patterns of light and shadow.
	34	My natural tendency is to put my experiences into words.
	35	When I'm working on something, part of my mind is occupied with other topics, such as what I'll be doing later, or things I'd rather be doing.
	36	I disapprove of myself when I have irrational ideas.
	37	I pay attention to how my emotions affect my thoughts and behaviour.
	38	I get completely absorbed in what I'm doing, so that all my attention is focused on it.
	39	I notice when my moods begin to change.

Appendix H

Five-factor mindfulness scale

Please rate each of the following statements using the scale provided. Write the number in the blank that best describes your own opinion of what is generally true for you.

1	2	3	4	5
Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true

	1	When I'm walking, I deliberately notice the sensations of my body moving.
	2	I'm good at finding words to describe my feelings.
	3	I criticise myself for having irrational or inappropriate emotions.
	4	I perceive my feelings and emotions without having to react to them.
	5	When I do things, my mind wanders off and I'm easily distracted.
	6	When I take a shower or bath, I stay alert to the sensations of water on my body.
	7	I can easily put my beliefs, opinions, and expectations into words.
	8	I don't pay attention to what I'm doing because I'm daydreaming, worrying, or otherwise distracted.
	9	I watch my feelings without getting lost in them.
	10	I tell myself I shouldn't be feeling the way I'm feeling.
	11	I notice how foods and drinks affect my thoughts, bodily sensations, and emotions.
	12	It's hard for me to find the words to describe what I'm thinking.
	13	I am easily distracted.
	14	I believe some of my thoughts are abnormal or bad and I shouldn't think that way.
	15	I pay attention to sensations, such as the wind in my hair or the sun on my face.
	16	I have trouble thinking of the right words to express how I feel about things.
	17	I make judgements about whether my thoughts are good or bad.
	18	I find it difficult to stay focussed on what's happening in the present.

	19	When I have distressing thoughts or images, I “step back” and am aware of the thought or image without getting taken over by it.
	20	I pay attention to sounds, such as clocks ticking, birds chirping, or cars passing.
	21	In difficult situations, I can pause without immediately reacting.
	22	When I have a sensation in my body, it’s difficult for me to describe it because I can’t find the right words.
	23	It seems I am “running on automatic” without much awareness of what I’m doing.
	24	When I have distressing thoughts or images, I feel calm soon after.
	25	I tell myself that I shouldn’t be thinking the way I’m thinking.
	26	I notice the smells and aromas of things.
	27	Even when I’m feeling terribly upset, I can find a way to put it into words.
	28	I rush through activities without being really attentive to them.
	29	When I have distressing thoughts or images I am able just to notice them without reacting.
	30	I think some of my emotions are bad or inappropriate and I shouldn’t feel them.
	31	I notice visual elements in art or nature, such as colours, shapes, textures, or patterns of light and shadow.
	32	My natural tendency is to put my experiences into words.
	33	When I have distressing thoughts or images, I just notice them and let them go.
	34	I do jobs or tasks automatically without being aware of what I’m doing.
	35	When I have distressing thoughts or images, I judge myself as good or bad, depending on what the thought / image is about.
	36	I pay attention to how my emotions affect my thoughts and behaviour.
	37	I can usually describe how I feel at the moment in considerable detail.
	38	I find myself doing things without paying attention.
	39	I disapprove of myself when I have irrational ideas.

Appendix I

Social Desirability Scale

Listed below are a number of statements concerning personal attitudes and traits.

Read each item and decide whether the statement is True or False as it pertains to you personally, then circle that answer.

1.	I like to gossip at times.	TRUE	FALSE
2.	There have been occasions when I took advantage of someone.	TRUE	FALSE
3.	I am always willing to admit it when I make a mistake.	TRUE	FALSE
4.	I always try to practice what I preach.	TRUE	FALSE
5.	I sometimes try to get even with people rather than forgive and forget.	TRUE	FALSE
6.	At times, I have really insisted on having things my own way.	TRUE	FALSE
7.	There have been occasions when I felt like smashing things.	TRUE	FALSE
8.	I never resent being asked to return a favour.	TRUE	FALSE
9.	I have never been irritated when people expressed ideas very different from my own.	TRUE	FALSE
10.	I have never deliberately said something that hurt someone’s feelings.	TRUE	FALSE

Appendix P

Positive and Negative Affect Scale

This scale consists of a number of words that describe different feelings and emotions. Read each item and circle the number that indicates to what extent you feel this way **RIGHT NOW**.

	Very slightly or Not at all	A Little	Moderately	Quite a Bit	Extremely
1. interested	1	2	3	4	5
2. distressed	1	2	3	4	5
3. excited	1	2	3	4	5
4. upset	1	2	3	4	5
5. strong	1	2	3	4	5
6. guilty	1	2	3	4	5
7. scared	1	2	3	4	5
8. hostile	1	2	3	4	5
9. enthusiastic	1	2	3	4	5
10. proud	1	2	3	4	5
11. irritable	1	2	3	4	5
12. alert	1	2	3	4	5
13. ashamed	1	2	3	4	5
14. inspired	1	2	3	4	5
15. nervous ....…	1	2	3	4	5
16. determined	1	2	3	4	5
17. attentive	1	2	3	4	5
18. jittery	1	2	3	4	5
19. active	1	2	3	4	5
20. afraid	1	2	3	4	5

Appendix J

Mediation analysis of the mediating role of attention control in the effect of mindfulness on worry.

The mediating effect of attentional control on mindfulness as a predictor of worry was then calculated using a version of the Sobel test developed for relatively small sample sizes (Preacher & Hayes, 2004), using 2000 bootstrap samples, shown in Tables A2 and A3, yielding a significant effect, $R^2 = .22$, $F(2,117) = 16.51$, $p < .001$. The effect of mindfulness on attention control was significant, as was the effect of attentional control on worry. Mindfulness had no significant direct effect on worry, but the total indirect effect was found to be significant, indicating that full rather than partial mediation had occurred. Confidence intervals found that this mediation was significant, 95% CI (-.29, -.09).

An alternative regression model was then analysed with mindfulness mediating the effect of attentional control on worry. Confidence intervals found that while the direct effect of attentional control on worry was significant, as was the direct effect of attentional control on worry, the effect of mindfulness on worry was insignificant, 95% CI (-.28, .20).

Table A2

Direct effects of variables using Sobel Test (2000 bootstrap samples) on attention control as a mediator of mindfulness predicting worry.

	B	S.E.	*t*
Direct effect of mindfulness on attentional control	.25	.06	4.59***
Direct effect of attentional control on worry	-.69	.16	-4.44***
Direct effect of mindfulness on worry	-.17	.10	-.17

Note: (*) = p < 0.5, (**) = p < 0.01, (***) = p < .001.

Table A3

Indirect effect of attention control as a mediator of mindfulness predicting worry.

	B	S.E.	z
Indirect effect of mindfulness on worry	-.18	.06	-3.21**

Note: (*) = p < 0.5, (**) = p < 0.01, (***) = p < .001.

Appendix K

Visual Analogue Scale of Mood and Anxiety

Put a vertical line at an appropriate point on the line below to indicate HOW YOU ARE FEELING RIGHT NOW with regard to that word.

ANXIOUS

Not at all	A little	Moderately	Quite a lot	Extremely

……………………………………………………………………………………………

ATTENTIVE

Not at all	A little	Moderately	Quite a lot	Extremely

……………………………………………………………………………………………

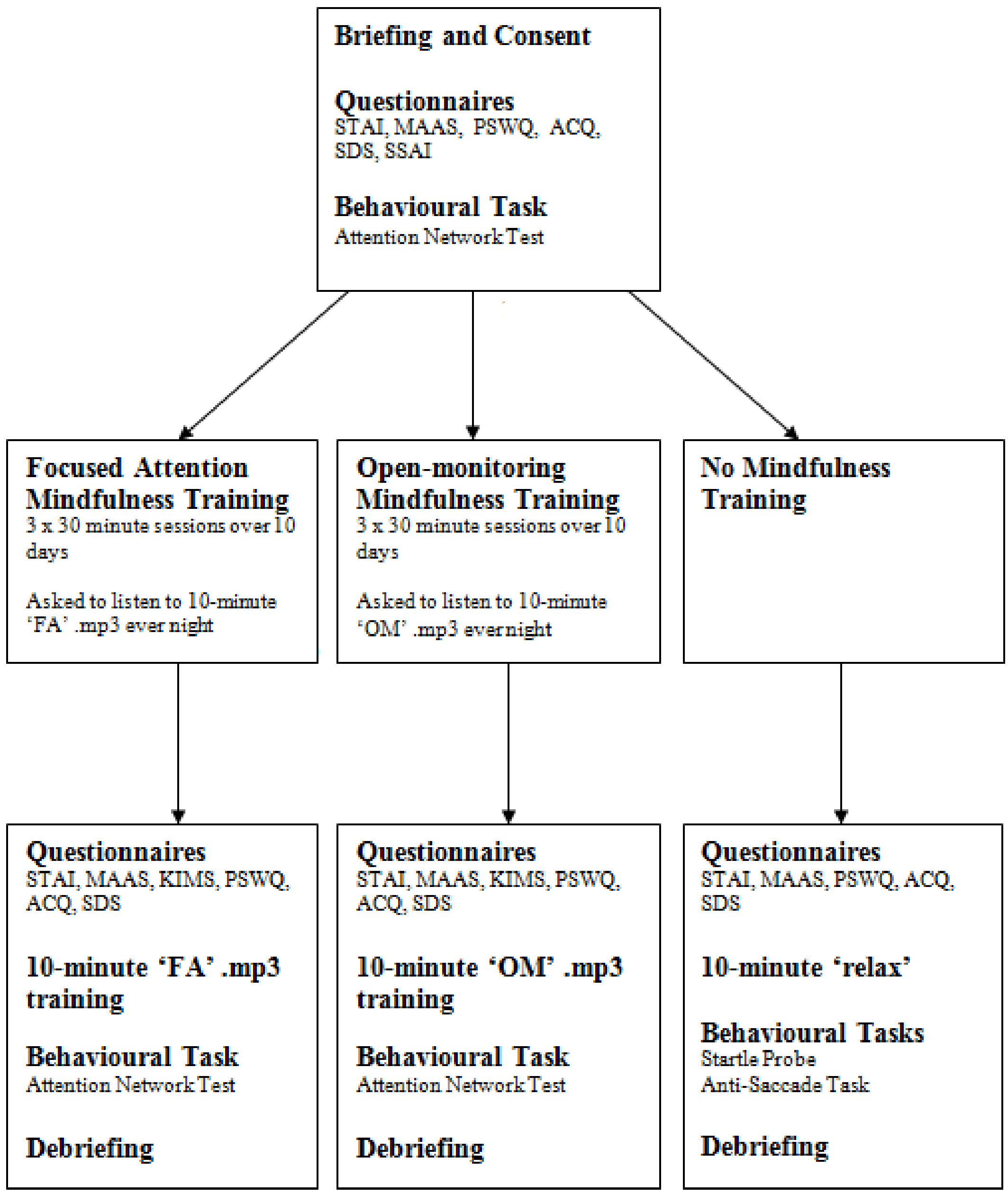
HAPPY

Not at all	A little	Moderately	Quite a lot	Extremely

……………………………………………………………………………………………

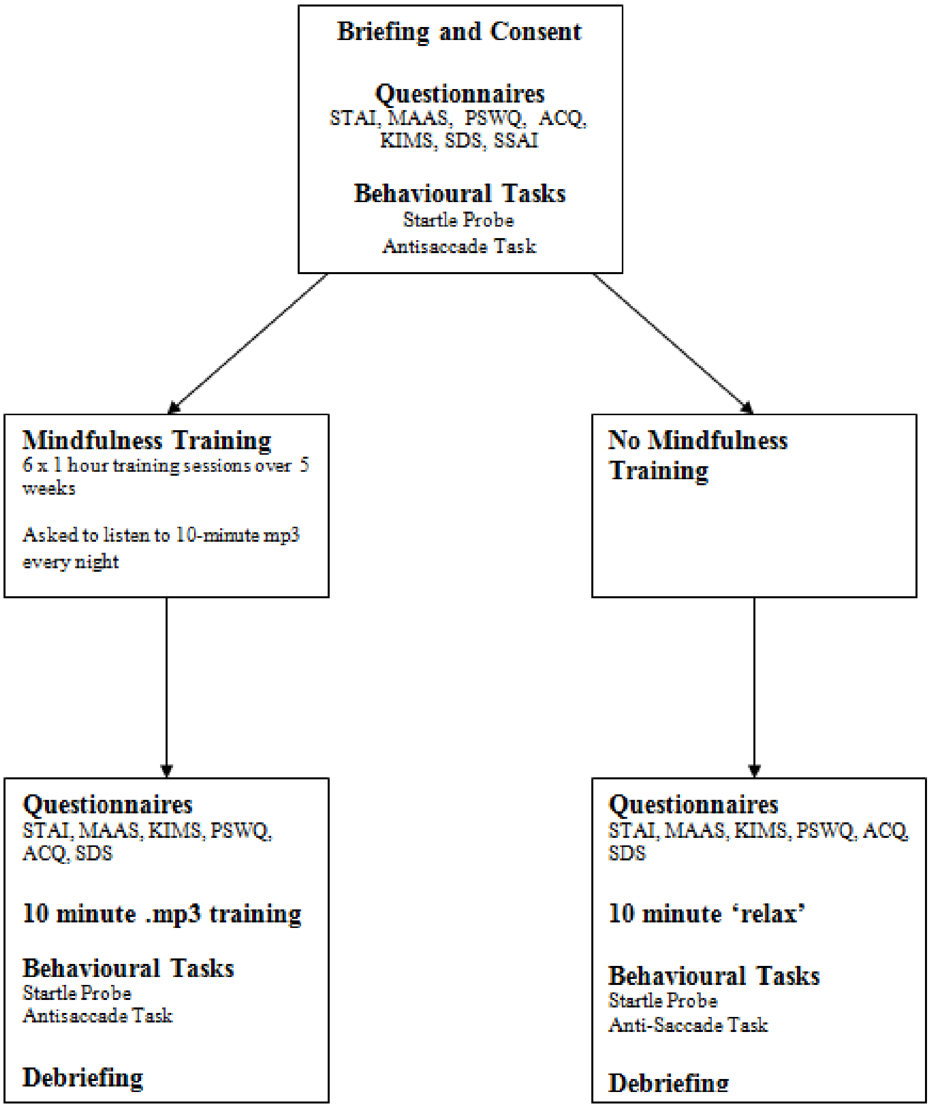
Appendix L

Chapter 3 (Experimental Study 1) Consort Diagram



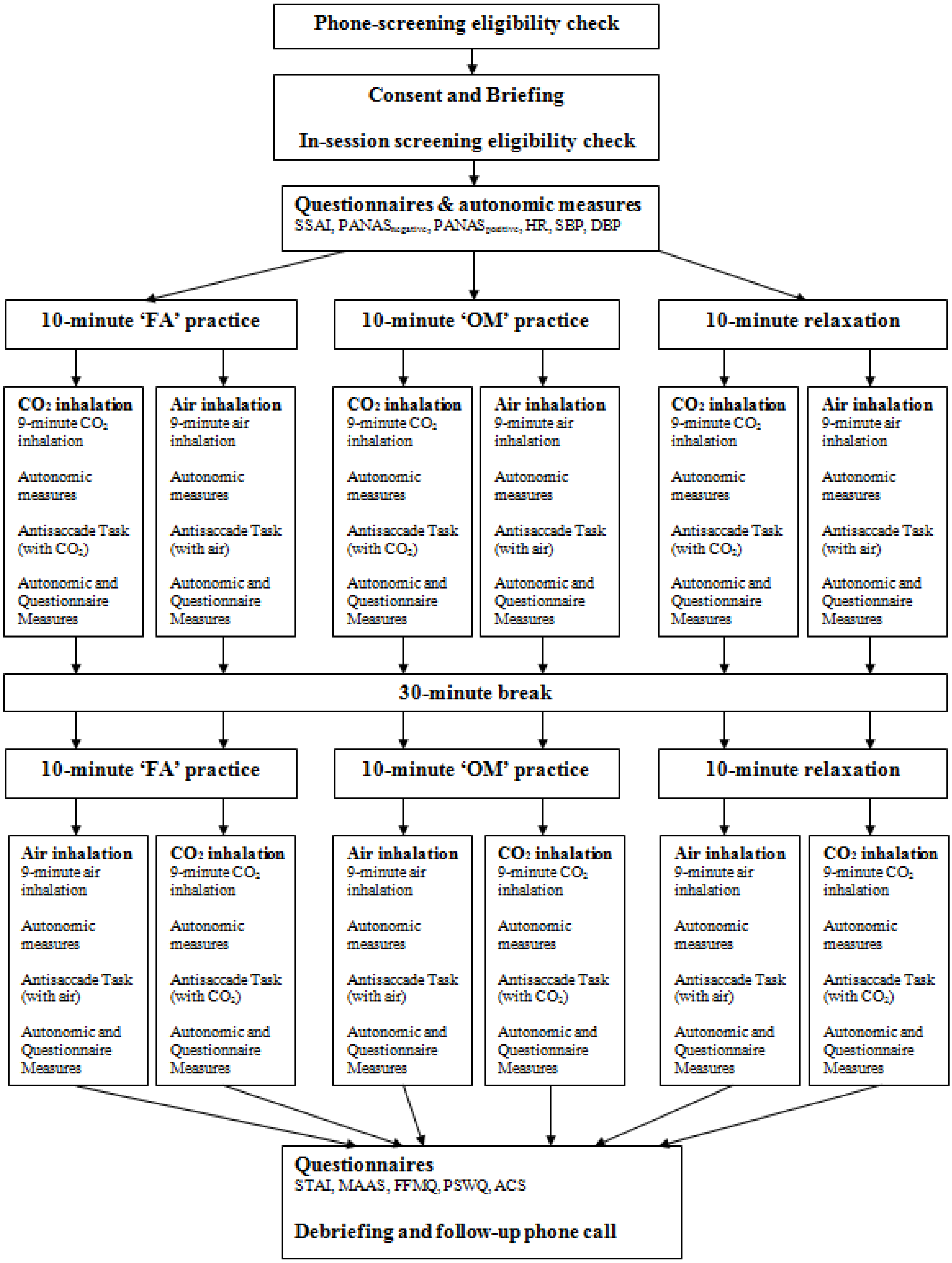
Appendix M

Chapter 4 (Experimental Study 2) Consort Diagram



Appendix N

Chapter 5 (Experimental Chapter 3) Consort Diagram



Appendix O

Mindfulness practice .mp3 files

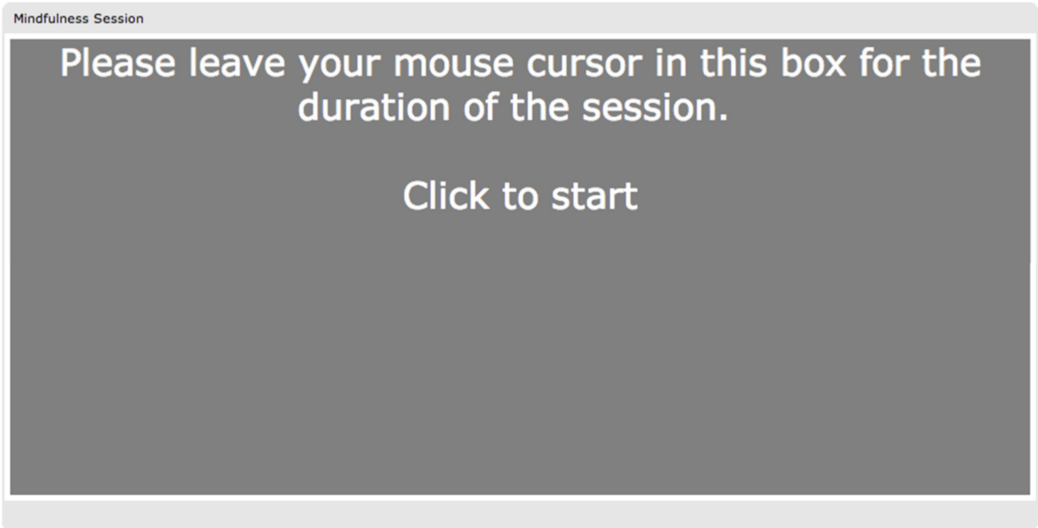
- Focused attention practice – used in Chapters 3 and 5.
    - http://www.youtube.com/watch?v=BUDPf0HVWL8

- Open-monitoring meditation practice – used in Chapters 3 and 5
    - http://www.youtube.com/watch?v=2NkZuh-ybE4

- Mindfulness practice – used in Chapter 4
    - http://www.youtube.com/watch?v=ewcXQRqRX9Y

Online mindfulness .mp3 delivery (Chapter 4).

After logging in with their individual ID number, participants used the following interface. If their mouse left the box the recording would stop, and if they did not follow the instructions ("please click the mouse" – see recording for Chapter 4) with 15 seconds, the recording would stop.



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