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Prophylactic Effects of Mindfulness: The Role of Mindfulness in the Treatment of Anxiety

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ABSTRACT

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PROPHYLACTIC EFFECTS OF MINDFULNESS: THE ROLE OF MINDFULNESS IN THE TREATMENT OF ANXIETY

by Jemma Emily Marshall

Mindfulness derives from meditative traditions and is a form of mental training that is increasingly incorporated into Western treatment approaches for common mental health problems. This thesis addresses the prophylactic effects of mindfulness practice and the implications for the treatment of anxiety. The first paper considers the role of attention as a predominant mechanism of mindfulness. The paper reviews the evidence for the effects of mindfulness on attentional subsets and suggests that mindfulness may in part exert its benefits by ameliorating maladaptive attentional processes that have been implicated in the aetiology of anxiety. The empirical paper reports the results of a randomised controlled trial that directly compared the prophylactic and differential effects of two mindfulness practices on pharmacologically-induced state anxiety and negative affect through inhalation of 7.5% carbon dioxide (CO_2). 60 participants engaged in 10 minutes of focused mindfulness, open mindfulness or relaxation prior to a 20-minute inhalation of 7.5% CO_2 or air. Consistent with the evidence-base, this study found that mindfulness reduced self-reported state anxiety and negative affect significantly more so than a period of relaxation. In the context of non-significant reductions in autonomic measures of arousal, these findings support that mindfulness exerts its benefits through specific rather than non-specific effects. The results are consistent with contemporary conceptualisations of mindfulness mechanisms that highlight the key role of attention and suggest that clinical effects are exerted through top-down control mechanisms that support emotion regulation.

Keywords: mindfulness, focused mindfulness, open mindfulness, attention, attentional subsets, anxiety

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Declaration of Authorship

I, Jemma E. Marshall, declare that the thesis entitled, Prophylactic Effects of Mindfulness: The Role of Mindfulness in the Treatment of Anxiety, and the work presented in the thesis are my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly while in candidature for a research degree at this University;
- 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;
- none of this work has been published before submission.

Signed:

Date: 23.05.2012

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Literature Review

Mechanisms of Mindfulness: Current Evidence for the Role of Attention and Implications for the Treatment of Anxiety

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MECHANISMS OF MINDFULNESS: CURRENT EVIDENCE FOR THE ROLE OF ATTENTION AND IMPLICATIONS FOR THE TREATMENT OF ANXIETY

by Jemma Emily Marshall

Whilst a growing evidence-base supports the efficacy and effectiveness of mindfulness in the treatment of anxiety, less is known about its mechanisms of action. Theoretical models and empirical evidence emphasise the role of attention within mindfulness and anxiety and suggest that attentional processes may be a key mechanism of mindfulness in the treatment of anxiety. This review addresses the current evidence for the role of attention as one mechanism of mindfulness and in the development and maintenance of anxiety. Consistent with contemporary hypotheses that attention facilitates the effects of various distinct but synergistic mechanisms through top-down processes, converging lines of evidence indicate positive changes in attentional subsystems following mindfulness and meditation. Moreover, preliminary evidence for the differential effects of distinct meditation styles on attentional subsets highlights the need to further explore the effects of disparate mindfulness practices. Similarities between those attentional processes involved in emotion dysregulation and those enhanced by mindfulness are also indicated. These findings suggest that mindfulness could be valuable in the prevention and treatment of anxiety and that enhanced attentional capabilities may primarily mediate these effects. Initial results evidencing the effectiveness of attentional training and mindfulness on attentional biases that confer vulnerability to anxiety corroborate these propositions. The review concludes with a critique of the current evidence-base and suggestions for future directions. It is advocated that continued conceptual and theoretical consideration, combined with further research in a number of directions, will be important to verify the available findings and to promote the use of mindfulness within different contexts.

Keywords: mindfulness, meditation, attention, attentional subsets, anxiety

1.0 The Role of Attention in Mindfulness and Implications for the Treatment of Anxiety

The concept of mindfulness has evolved from Eastern cultural, contemplative and philosophical traditions and meditative practice, and is traditionally described as "paying attention on purpose, in the present moment, and non-judgementally" (Kabat-Zinn, 2003, p. 145). Whilst the term encompasses various techniques, most involve directing attention to the experience of thoughts, sensations and emotions, and simply observing them as they occur. Contemporary mindfulness usually involves practices such as sitting or walking meditation or mindful movements and is seldom associated with cultural, philosophical or religious values (Hölzel, Lazar, et al., 2011).

Research suggests that mindfulness has widespread beneficial effects; mindfulness enhances well-being and alleviates psychological and physical problems in clinical and non-clinical populations, with at least medium-sized effect sizes (e.g., d = .53-.59; Baer, 2003; Grossman, Niemann, Schmidt, & Walach, 2004). Mindfulness techniques have been adapted and included as integral components in interventions such as mindfulness-based stress reduction (MBSR; Kabat-Zinn, 1990), mindfulness-based cognitive therapy (MBCT; Segal, Williams, & Teasdale, 2002) dialectical behaviour therapy (DBT; Linehan, 1993) and acceptance and commitment therapy (ACT; Hayes, Strosahl, & Wilson, 1999)[1]. Meta-analytic reviews indicate that mindfulness-based interventions have yielded medium-to-large effects in the treatment of anxious and affective disorders (d = .54; Grossman et al., 2004; Hedge's g = .95-.97; Hofmann, Sawyer, Witt, & Oh, 2010). Furthermore, preliminary evidence demonstrates that mindfulness is efficacious across anxiety disorder subtypes, including generalised anxiety disorder (GAD), panic disorder (e.g., Kabat-

[1] Please refer to the Glossary for further details of these interventions, meditation traditions and neuroanatomical terms discussed within this review.

Zinn et al., 1992; Kim et al., 2009) and social anxiety disorder (e.g., Goldin & Gross, 2010; Koszycki, Benger, Shlik, & Bradwejn, 2007; Piet, Hougaard, Hecksher, & Rosenberg, 2010; Vøllestad, Sivertsen, & Nielsen, 2011).

These findings highlight that mindfulness could be an innovative, time-efficient and cost-effective intervention for anxiety, in accordance with national imperatives (Department of Health, 2011; National Institute for Health and Clinical Excellence [NICE], 2011; The British Psychological Society, 2009). This is particularly important since anxiety disorders are highly prevalent; with a one-week and lifetime prevalence of 1.1-4.4% and 1.4-12.1% across England, respectively (McManus, Meltzer, Brugha, Bebbington, & Jenkins, 2009), and a 12-month and lifetime prevalence of 12% and 17-21% across Europe, respectively (Wittchen & Jacobi, 2005). Anxiety is associated with a range of adverse personal and societal outcomes, such as reduced social and occupational functioning, diminished quality of life (e.g., Maier et al., 2000), co-morbid illness (Sareen et al., 2006), morbidity, increased utilisation of health services (Krisanaprakornkit, Sriraj, Piyavhatkul & Laopaiboon, 2009) and substantial economic burden (Wittchen & Jacobi, 2005). Moreover, the effective treatment of anxiety is restricted in many cases by limitations of existing pharmacotherapeutic and psychotherapeutic approaches. Whilst the availability of psychological interventions, such as cognitive behavioural therapy, is often limited (NICE, 2011), pharmacological treatments are constrained by side effects, an inability of some to tolerate pharmacotherapy and concerns of escalating prescription rates in the context of uncertain long-term effects of some medications (Kirsch et al., 2008). Additionally, effect sizes for pharmacological treatments are small-to-medium and relapse and residual symptoms continue to be problematic in both cases (Durham, Higgins, Chambers, Swan, & Dow, 2011; Hofmann & Mathew, 2008).

Little is known about the mechanisms through which mindfulness exerts its benefits and a greater understanding is required to establish the specificity and applicability of mindfulness within various contexts and in the treatment of different disorders. Theoretical and conceptual accounts, experiential reports and empirical evidence highlight the role of attention within mindfulness and anxiety. Therefore, this review addresses current evidence for the role of attention as one mechanism of mindfulness and discusses the implications for the treatment of anxiety. A brief overview of mindfulness mechanisms is presented. The evidence for positive changes in attentional subsets following mindfulness and meditation, as well as differential effects of disparate meditation styles, is subsequently addressed. The role of attention in anxiety is then considered and preliminary evidence for mindfulness as a treatment of anxiety through attentional mechanisms is reviewed. Theoretical, conceptual and methodological constraints of the evidence-base and avenues for future study are subsequently considered.

2.0 Methodology

A literature search was completed using PsychInfo, MEDLINE, PsychARTICLES, Cochrane Collaboration databases, the internet search engine Google Scholar and references of retrieved articles. Primary search terms were *mindfulness**, *meditation*, *mindfulness-based stress reduction*, *mindfulness-based cognitive therapy*, *mindfulness and attention*, *meditation and attention* and *attentional bias*, intersected with *anxiety**. The search included papers written in English and published before February 2012. Reasons for exclusion included: (i) reference to non-adult populations, (ii) uncontrolled trials, (iii) qualitative or speculative reports and (iv) interventions in which formal mindfulness was not the primary component. This includes psychological approaches such as ACT and DBT and meditations such as Transcendental meditation, yoga-based meditations (e.g., Kundalini yoga) and compassion-based meditations (e.g., Loving-Kindness meditation/planā) since these are qualitatively and quantitatively different in conceptualisation and practice from mindfulness (Chiesa & Malinowski, 2011; Travis & Shear, 2010).

3.0 Mindfulness: Definitions and Mechanisms

3.1 Definitions

Bishop, Lau, et al. (2004) provide a two-component model of mindfulness that includes (i) the regulation of attention so that it is maintained on the immediate experience and (ii) an orientation of curiosity and acceptance. Despite some theoretical and operational variability, most definitions highlight these elements (e.g., Baer, 2003; Brown & Ryan, 2003; Lutz, Slagter, Dunne, & Davidson, 2008).

The study of attention in meditation has largely contributed to our understanding of mindfulness mechanisms. Distinctions are made between focused attention/concentrative meditation (FA) and open monitoring (OM), in attempts to dismantle integral parts of heterogeneous meditation styles. Whilst FA describes attention that is sustained on a chosen object, such as the breath, OM involves monitoring the content of experience non-reactively and without secondary processing to encourage an awareness of emotional and cognitive patterns (e.g., Lutz, Slagter, et al., 2008). Whilst some suggest that FA and OM are distinct (e.g., Dunn, Hartigan, & Mikulas, 1999), this has been contentious since OM may represent a progression of FA (Lutz, Brefczynski-Lewis, Johnstone, & Davidson, 2008; Lutz, Dunne, & Davidson, 2008). Distinctions between mindfulness and meditation are warranted since meditation is typically longer, more extensive and practiced in the context of philosophical and cultural beliefs that are qualitatively different from contemporary mindfulness (Harris, 2008). However, the meditation literature can inform our understanding of mindfulness processes since both FA and OM encompass attentional qualities inherent in mindfulness and represent similar distinctions observed within mindfulness practices, described as focused mindfulness and open mindfulness. Whilst focused mindfulness describes sustained attention on a chosen object and therefore is comparable to FA, open mindfulness cultivates a wider awareness of experiences and is similar to OM.

3.2 Mechanisms

In contrast to suggestions that mindfulness exerts its benefits through one mechanism (Brown & Ryan, 2003; Carmody, 2009), others posit complex frameworks comprising of several elements (Baer, 2003, 2009; Brown, Ryan, & Creswell, 2007; Coffey, Hartman, & Fredrickson, 2010; Grabrovac, Lau, & Willett, 2011; Hölzel, Lazar, et al., 2011; Shapiro, Carlson, Astin, & Freedman, 2006). Contemporary perspectives largely suggest that a number of distinct but interrelated mechanisms work synergistically (Garland, Gaylord, & Fredrickson, 2011; Grabrovac et al., 2011; Hölzel, Lazar, et al., 2011; Shapiro et al., 2006). Attention is consistently proposed as a mechanism of mindfulness (e.g., Baer, 2009; Brown & Ryan, 2003; Carmody, 2009; Garland et al., 2011; Hölzel, Lazar, et al., 2011; Shapiro et al., 2006), and some suggest that it may be a prerequisite for other mechanisms to exert their effects (Baer, 2009; Dorjee, 2010; Hölzel, Lazar, et al., 2011). Other mechanisms that have been commonly discussed include: self-focused awareness, emotion regulation, relaxation and enhanced mind-body functioning, acceptance and meta-cognitive shifts.

3.2.1 Self-focused awareness. Interoceptive awareness describes an awareness of internal bodily sensations whilst exteroceptive awareness reflects the perception of stimuli originating from outside of the body. Preliminary neuroscientific evidence suggests that mindfulness is associated with functional and structural changes in areas related to interoceptive and exteroceptive awareness. The insulae have been implicated within diverse functions including homeostasis, perception, cognitive control, motor control and, more recently, interoceptive awareness (Hölzel, Lazar, et al., 2011). Regions such as the secondary somatosensory cortex (involved in the processing of sensory stimuli) and the temporo-parietal junction have been implicated in self-distinction processes and exteroceptive awareness (Hölzel, Lazar, et al., 2011). Alterations in these areas are indicated following meditation (Brown & Jones, 2010; Cahn, Delorme, & Polich, 2010; Grant, Courtemanche, & Rainville, 2011; Hölzel et al., 2008; Lazar et al., 2005; Newberg et al., 2010) and mindfulness (Farb et al., 2007; Farb et al., 2010; Gard et al., 2010; Hölzel, Carmody, et al., 2011; Zeidan et al., 2011). Research employing heartbeat detection tasks as a measure of interoceptive awareness has not indicated an improved self-focus in meditators (Khalsa et al., 2008; Nielsen & Kaszniak, 2006). However, the sensitivity of this task as an index of mindful awareness has been challenged (Hölzel, Lazar, et al., 2011).

3.2.2 Emotion regulation. Cognitive-based emotion regulation strategies[2], such as processes of affective labelling, exposure, extinction and associated decreased rumination and avoidance, are often cited as mindfulness mechanisms (Baer, 2003, 2009; Brown et al., 2007; Coffey et al., 2010; Garland et al., 2011; Hölzel, Lazar, et al., 2011). Improved emotion regulation following mindfulness practice has been consistently demonstrated through questionnaire studies (Arch & Craske, 2006; Goldin & Gross, 2010; Jain et al., 2007; Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010; Kiken & Shook, 2011). Neuroscientific evidence also suggests that mindfulness involves changes in structures that facilitate emotion regulation. During emotion regulation, the prefrontal cortex (PFC; implicated in higher-order functions, such as planning, decision-making and behaviour regulation) is conceptualised to

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[2] Emotion regulation is a process through which individuals consciously and non-consciously experience and express their emotions. Affective labelling describes the process of expressing feelings by describing them with words and has been thought to help individuals manage negative emotional experiences. Exposure and extinction refer to a conditioning process in which a previously learned response to a cue is eliminated following repeated presentation of the cue and habituation to associated emotional reactions.

down-regulate subcortical structures that process emotion, such as the amygdala. This process is thought to suppress fear and therefore enable increased behavioural control. Research consistently indicates functional alterations following mindfulness, including (i) the activation of the PFC (Barnhofer, Chittka, Nightingale, Visser, & Crane, 2010; Creswell, Way, Eisenberger, & Lieberman, 2007; Farb et al., 2007; Modinos, Ormel, & Aleman, 2010) and (ii) an attenuated amygdala response (Creswell et al., 2007; Goldin & Gross, 2010). Structural changes have also been observed in hippocampal areas implicated in the top-down control of emotional processes following mindfulness (Hölzel, Carmody, et al., 2011) and meditation (Hölzel et al., 2008; Luders, Toga, Lepore, & Gaser, 2009). There is also some preliminary evidence of changes in neurochemicals that modulate affect, such as dopamine, melatonin and serotonin (see Rubia, 2009 for a review). However, there continues to be some controversy within this area; some researchers propose that greater neural activity within prefrontal regions involved in cognitive change supports a conceptualization of enhanced emotion regulation associated with mindfulness as "positive reappraisal" (e.g., Garland et al., 2011). Positive reappraisal has been described as "the adaptive process through which stressful events are reconstructed as beneficial, meaningful or benign (e.g., thinking that one will learn something from a difficult situation)" (Hölzel, Lazar, et al., 2011, p. 544). In contrast, others have sometimes observed decreased neural activity in these areas, conceptualised as "non-appraisal" (Gard et al., 2010; Grant et al., 2011). Further research is required to confirm hypotheses that these discrepancies are related to degree of practice and that increased mindfulness is associated with reductions in the degree of required prefrontal control (Hölzel, Lazar, et al., 2011).

3.2.3 Relaxation and enhanced mind-body functioning. Meditation and mindfulness are associated with improved physical health (Davidson et al., 2003; Jacobs et al., 2010; Vestergaard-Poulsen et al., 2009) and reduced autonomic arousal, indicative of a state of relaxation (e.g., Campbell, Labelle, Bacon, Faris, & Carlson, 2012; Carlson, Speca, Patel, & Faris, 2007; Jensen, Vangkilde, Frokjaer, & Hasselbalch, 2011; Palta et al., 2012; Zeidan, Johnson, Gordon, & Goolkasian, 2010). Research indicates that mindfulness does not exert its benefits solely through relaxation (e.g., Jain et al., 2007; Jensen et al., 2011; Semple, 2010). However, some suggest that relaxation facilitates emotion regulation (Hölzel, Lazar, et al., 2011) or that relaxation (Baer, 2003) or enhanced and integrated mind-body functioning (Brown et al., 2007) directly constitute one of a number of mindfulness mechanisms.

3.2.4 Acceptance and meta-cognitive shifts. Theoretical models and experiential accounts consistently ascribe that acceptance and meta-cognitive shifts, variously described as insight (e.g., Brown et al., 2007), decentering and reperceiving (e.g., Carmody, Baer, Lykins, & Olendzki, 2009; Shapiro et al., 2006) are important mechanisms of mindfulness. The associated construct of “non-attachment”, described as “an acceptance of, or willingness to be with what is, in contrast to states of mind that involve avoidance, control and the investment of personal well-being in altering circumstances or attaining goals” (Brown et al., 2007, p. 227) has also been discussed (Brown et al., 2007; Coffey et al., 2010). Most suggest that mindfulness supports a shift to a detached identification with the elements of experience and enhanced cognitive flexibility (Shapiro et al., 2006), which reduces automatic, habitual or impulsive reactions by increasing the range and adaptability of available responses (Bishop, Lau, et al., 2004).

Difficulty operationalizing these terms has hindered empirical research within this area (Hölzel, Lazar, et al., 2011). However, questionnaire studies suggest that a meta-perspective develops following meditation (Emavardhana & Tori, 1997; Haimerl & Valentine, 2001) and mindfulness (Feldman, Greeson, & Senville, 2010). Neuroimaging studies have preliminarily indicated that mindfulness results in neural changes in regions implicated in self-referential processing. The default mode network (DMN) is an anatomical network implicated in the generation of spontaneous and stimulus-independent thought and the integration of self-referential information into autobiographical memory. Anatomical subsystems primarily include regions of the medial PFC, posterior cingulate cortex, precuneus and the parietal lobe (Hölzel, Lazar, et al., 2011). Research has shown functional changes within DMN activity and connectivity following meditation (Brewer et al., 2011; Jang et al., 2011) and MBSR (Farb et al., 2007; Kilpatrick et al., 2011). The posterior cingulate cortex, temporo-parietal junction and hippocampus are also hypothesised to form a network implicated in self-projection processes in which autobiographical information influences the processing of other perspectives (Hölzel, Lazar, et al., 2011). Cortical changes in these areas (Hölzel, Carmody, et al., 2011) also support changes in meta-cognitive shifts and increased acceptance following meditation.

4.0 The Effects of Mindfulness Practice on Attentional Subsets

Models of attention suggest three functionally separate neural networks underlying attentional processes of alerting (alternatively referred to as sustained attention or vigilance), orienting (or selective attention or concentration) and executive attention (or conflict monitoring or attentional control) (McDowd, 2007; Posner & Petersen, 1990; Posner & Rothbart, 2007). Alerting refers to the maintenance of an alert or vigilant state, orienting regulates attention to a subset of sensory inputs and executive attention resolves conflicts among thoughts, feelings and responses (e.g., Posner, 2008). Attention switching/shift of attention, or “the ability to change attentive focus in an adaptive and flexible manner” (Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991, p. 112) has been suggested as an additional subcomponent. Empirical research has increasingly examined the attentional blink, which can be described as “a lapse in attention following a stimulus within a rapid stream of presented stimuli” (Hölzel, Lazar, et al., 2011, p. 541) and change blindness, which is the “the failure to detect large changes to objects or scenes” (Hodgins & Adair, 2010, p. 2). Both phenomena are conceptualised to represent information processing deficits that reflect dysfunction within all domains of attention and a range of executive functions, including working memory, response selection and inhibitory processes (Dux & Marois, 2009; Simons & Levin, 1998).

The evidence-base suggests that mindfulness is associated with attentional improvements and that even moderately brief mindfulness practice can improve attentional subsets of alerting, and particularly orienting and executive attention. Significant positive effects have been observed using varied methodologies and in comparison to both active and inactive control groups. These findings support that attention is an important mechanism of mindfulness and that it might be a prerequisite for other mechanisms of mindfulness to exert their benefits. The evidence-base also indicates that FA and OM may be associated with differential attentional benefits, with implications for the study of mindfulness. Numerous experimental paradigms have been used to examine the role of attention within mindfulness and anxiety; the main neuropsychological paradigms discussed within this review are described in Table 1.

Table 1

Main Neuropsychological Paradigms Discussed Within the Review

Ambiguous Image Perspective-Switching Task (e.g., Hodgins & Adair, 2010)	This task is thought to exemplify the strength of top-down processes (Long & Toppino, 2004) and provides a measure of perspective-switching. Participants are required to identify ambiguous figures that can be viewed in two alternative ways as quickly as possible.
Attention Network Test (ANT; Fan, McCandliss, Sommer, Raz & Posner, 2002)	The ANT provides measures of alerting, orienting and executive attention. It is a combination of a cued reaction time (RT) task and a flanker task and requires participants to determine whether a central arrow points left or right, which is "flanked" by congruent or incongruent stimuli.
Change Blindness Flickering Task (Rensink, O'Regan, & Clark, 1997)	This task assesses change blindness. Participants are required to view a number of images and identify the change in each scene as quickly as possible.
Continuous Performance Test (Halperin, Sharma, Greenblatt, & Schwartz, 1991)	This test measures alerting and orienting. Participants are required to press a computer key following the presentation of any letter apart from X and to inhibit responses to the letter X.
d2-Test of Attention (Brickenkamp & Zilmer, 1998)	This test is a timed measure of orienting. It consists of 14 rows, each consisting of 47 characters. Participants must discriminate targets from visually-similar non-targets by striking them with two dashes.
Dot Probe Task (MacLeod, Mathews, & Tata, 1986)	Participants are presented with a pair of stimuli for a brief duration (e.g., 500ms) before one of the stimuli is replaced by a dot. Participants must indicate the location of the dot as quickly as possible. Attentional biases are inferred from different response times towards probes that replace neutral stimuli (i.e. incongruent trials).
Global-Local Letters task (e.g., Chan & Woollacott, 2007)	This task is a measure of orienting. Participants are required to read letters that are comprised of a collection of smaller letters. Participants are required to process either the large letter or the smaller letters that constitute the large letter.
Internal Switching Task (Lo & Allen, submitted for publication)	This task has been employed as a measure of alerting and switching effects. Participants are required to maintain a count of how many words of a given category are serially presented on a computerised display and press a key upon completion.
n-Back Task (e.g., Zeidan, Johnson, Diamond, David, & Goolkasian, 2010)	This test is a variant of the Continuous Performance Test and provides a measure of information processing speed, working memory, alerting and executive attention. Participants are presented with a sequence of letters and indicate whether the letter is the same as a digit presented *n* intervals previously.
Object Detection Task (Hollingworth & Henderson, 1998)	This test measures object perception and executive attention. Participants are required to identify whether a given object is present within a visually cluttered scene. Consistency effects are indicated by increased errors or RT to detect objects within conceptually inconsistent rather than consistent scenes.
Spatial Cueing Task (e.g., Fox, Russo, Bowles, & Dutton, 2001; Posner, 1980)	This task measures spatial attentional allocation/control. Participants are required to indicate the location of target stimuli, which are preceded by a valid or invalid cue. Attentional biases are demonstrated by faster RTs to valid threat-cue trials compared to neutral-cue trials.
Stroop (Stroop, 1935)	This task is a measure of attention, cognitive flexibility and processing speed. Participants are required to read the colour that a word is printed in rather than the word itself. The modified variant requires that participants repeat this procedure whilst ignoring the semantic content of the word. Attentional biases are inferred from increased RT to report the colour of threat words, compared to neutral words.
Visual search tasks (e.g., Öhman, Flykt, & Esteves, 2001; Rinck, Becker, Kellermann, & Roth, 2003)	Similar to the object detection task, in this task participants are required to detect a target embedded within distracting stimuli. Attentional biases are reflected within faster RTs to detect a threat target embedded within neutral stimuli or slower RTs to detect a neutral target embedded within threat stimuli.
Wilkins Counting Test (Wilkins, Shallice, & McCarthy, 1987)	A measure of alerting; participants are required to count a series of binaural auditory bleeps presented at different rates.

4.1 Alerting

Converging evidence consistently demonstrates the positive effects of meditation and mindfulness on alerting capabilities. Case-control studies that have compared experienced meditators to novice practitioners or control participants indicate that extensive meditation is associated with improved alerting (Carter et al., 2005; Dunn et al., 1999; Lazar et al., 2000; Pagnoni & Cekic, 2007; Short et al., 2010; Valentine & Sweet, 1999), although Carter et al. (2005) found this was only true for FA and not compassion-based meditation. Similarly, although Jha, Krompinger, and Baime (2007) found non-significant differences between meditation-naïve participants allocated to an 8-week MBSR programme and wait-list controls, participants with an average of 60 months prior experience of FA showed significantly improved alerting compared to MBSR and control participants, as indexed by significant reductions in reaction time (RT) on the Attention Network Test (ANT). Valentine and Sweet (1999) reported that, despite a lack of difference between FA and OM meditators' performance on the Wilkins Counting Test of alerting when the stimulus was expected, OM practitioners performed significantly better when the stimulus was unexpected, intimating a more distributed attentional focus following OM. Randomised controlled trials (RCTs) indicate similar results. MacLean et al. (2010) found that following a 3-month intensive FA meditation retreat, experienced meditators demonstrated improved visual discrimination that was associated with greater perceptual sensitivity and alerting, compared to wait-list controls. Similarly, Lutz et al. (2009) found that 3 months of Vipassanā (combined FA and OM meditation) by meditators with a baseline average experience of 2,967 hours was associated with improved alerting. Enhanced alerting was evidenced by attenuated RT variability of target tones on a dichotic listening task representative of decreased attentional processing and electroencephalographic (EEG) data of increased theta-band phase consistency of oscillatory neural responses over anterior brain regions. Chambers, Lo, and Allen (2008) also found that following a 10-day Vipassanā retreat, meditation-naïve individuals performed significantly better than control participants on affective (but not neutral) trials of the Internal Switching Task.

Neuroscientific evidence has similarly indicated improved alerting following meditation. Kozasa et al. (2012) used functional magnetic resonance imaging (fMRI) to indicate that regular meditators (combined FA and OM) activated fewer brain areas related to attentional networks and motor control in order to achieve the same performance on incongruent trials of an adapted Stroop task as non-meditators. Reduced activity was found in regions implicated in executive function, such as the middle frontal gyrus, middle temporal gyrus and postcentral gyrus, and motor control, including the precentral gyrus and lentiform nucleus. In contrast to non-meditators, meditators processed incongruent and congruent stimuli similarly, suggesting that meditation improved efficiency, perhaps through heightened alerting and executive attention. These effects were shown under rest conditions, providing some evidence for the prophylactic effects of meditation even when an individual is not meditating. Similarly, Brefczynski-Lewis, Lutz, Schaefer, Levinson, and Davidson (2007) examined the neural correlates of FA on external visual stimuli in experienced meditators and found activation in neuroanatomical networks relevant to alerting, such as the dorsolateral PFC, hippocampal areas and the visual cortex, compared to incentive controls. Pagnoni and Cekic (2007) also found that Zen meditators (combined FA and OM) did not show expected negative correlations between age and (i) global and regional gray matter volume in the putamen, a structure implicated in attentional processing (Nieoullon, 2002), and (ii) a computerised alerting task. In contrast, negative correlations were observed as expected in control participants.

Preliminary studies indicate that brief focused mindfulness is also associated with improved alerting. Zeidan, Johnson, Diamond, et al. (2010) found that whilst participants that had either engaged in mindfulness or listened to an audio-book reported improved mood, only those who had received 4 days of mindfulness training demonstrated improved alerting on the *n*-Back Task and reduced anxiety. Similarly, Semple (2010) compared a 4-week focused mindfulness group, a progressive muscle relaxation group and wait-list controls. Mindfulness practice was associated with significant improvements in alerting on the Continuous Performance Test that were not mediated by relaxation or practice effects.

In contrast to these findings, some researchers have not found associations between improved alerting and mindfulness training (Anderson, Lau, Segal, & Bishop, 2007; Cusen, Duggan, Thorne, & Burch, 2010; McMillan, Robertson, Brock, & Chorlton, 2002; Polak, 2009) and meditation (Josefsson & Broberg, 2011; Tang et al., 2007).

4.2 Orienting

The evidence-base indicates improved orienting following meditation and mindfulness. Most case-controlled studies demonstrate enhanced orienting in experienced meditators. van den Hurk, Giommi, Gielen, Speckens, and Barendregt (2010) found that experienced Vipassanā practitioners demonstrated significantly reduced orienting network effects on the ANT, compared to control participants. Moore and Malinowski (2009) similarly found that self-reported mindfulness levels and meditation experience were positively correlated with orienting ability in a group of meditators largely oriented towards OM, as measured by the d2-Test of Attention (*r* = .51) and the Stroop task (*r* = .62). Additionally, Hodgins and Adair (2010) demonstrated that meditators were able to disengage more quickly from incorrectly cued spatial information and more flexibly redirect to novel stimuli compared to non-meditators. Finally, although Chan and Woollacott (2007) found no correlation between meditation experience and the congruency effect score on the Global-Local Letters Task, meditation experience was correlated with improved RT within all trials, reaching significance in the global condition. Brefczynski-Lewis et al. (2007) also found that in comparison to controls, meditators demonstrated increased activation within areas associated with orienting during FA, such as the superior frontal sulcus and intraparietalsulcus, compared with a rest condition.

Research also indicates that shorter mindfulness practice is associated with improved orienting, suggesting that orienting effects occur during early phases of mindfulness training. Jensen et al.'s (2011) RCT found that participants that attended an 8-week MBSR programme had significantly improved orienting at post-test as measured by the d2-test of attention, compared to a non-mindfulness stress reduction group (NMSR) and inactive control group. NMSR was structurally equivalent to MBSR but did not include meditation or practices that fostered the development of a non-judgemental attitude. The study also demonstrated that test effort can significantly confound findings; attentional effects of MBSR, NMSR and control participants given a financial incentive to improve their performance at post-test were comparable or significantly greater for those given a financial incentive on all RT measures, except on the d2-Test of Attention, on which MBSR participants were significantly better than controls. Friese, Messner, and Schaffner (2012) similarly found that a 2-day mindfulness induction incorporating focused and open mindfulness practices offered prophylactic effects under conditions of low resources. Poorer performance on the d2-Test of Attention was observed by participants who had previously engaged in an emotion suppression task that diminished self-control resources. However, participants who engaged in mindfulness following emotion suppression performed similarly on the same test as participants who had not exerted their self-control. Interestingly, Jha et al. (2007) found that MBSR participants primarily practicing focused mindfulness demonstrated significantly enhanced orienting on the ANT, in comparison to expert meditators and control participants. Whilst this supports the early development of orienting abilities following mindfulness, the finding that novice practitioners were superior to experienced practitioners may have been influenced by substantial variation in the previous experience of expert meditators (4-360 months).

Neuroscientific evidence further supports enhanced orienting following mindfulness. Kerr et al. (2011) used magnetoencephalographic recording of the primary somatosensory neocortex (involved in the processing of sensory stimuli) to examine the modulation of alpha rhythms following MBSR. Modulation of alpha rhythms in the primary somatosensory neocortex are thought to be involved in orienting by regulating thalamocortical sensory transmission (Capotosto, Babiloni, Romani, & Corbetta, 2009). Kerr et al. found that during a tactile detection task, mindfulness practitioners demonstrated enhanced alpha power modulation in the primary somatosensory neocortex in response to a cue, compared to pre-test and wait-list controls. Lakey, Berry and Sellers (2010) also report that a 6-minute focused mindfulness induction was associated with significantly improved accuracy on a brain-computer interface task assessing task-devoted concentration. EEG data also indicated that mindfulness was associated with significantly greater P300 amplitudes that represent an improved orienting response (Andreassi, 2007), compared to control participants.

A small proportion of research has found no significant differences within orienting networks following mindfulness (McMillan et al., 2002; Polak, 2009; Semple, 2010) and FA (Tang et al., 2007).

4.3 Executive Attention

Case-controlled trials demonstrate that meditators have improved executive attention. Moore and Malinowski (2009) found moderate-to-large positive correlations between trait mindfulness and the Stroop task, which may represent improved attentional control and cognitive flexibility. Similarly, Chan and Woollacott (2007) found a significant negative correlation between Stroop interference and meditation experience (r = -.31), although no differences between FA and OM were observed. Although van den Hurk, Giommi, et al. (2010) did not observe a significant association between Vipassanā meditation and reduced error on the Stroop task, a trend towards significance was found (p = 0.07). Improved executive attention has also been demonstrated following brief FA inductions in novice participants, as measured by the ANT (Tang et al., 2007; Tang et al., 2009) and Stroop performance, which was not mediated by reduced arousal (Wenk-Sormaz, 2005).

Similarly, improved executive attention on the *n*-Back Task was found following 4 days of focused mindfulness (Zeidan, Johnson, Diamond, et al., 2010), in support of propositions that executive attention is enhanced during early phases of mindfulness. Additionally, Jha et al. (2007) found that although experienced meditators showed significantly improved executive attention on baseline ANT measures, there was no significant difference between meditators and MBSR participants at post-test. It is possible that non-significant differences between groups at post-test could reflect improvements made by participants following MBSR or, alternatively, effects of task exposure or floor effects in RT (Jha et al., 2007).

Improved executive attention has been associated with reduced neuronal reactivity to distractors due to greater top-down control. Evidence suggests that the anterior cingulate cortex (ACC) facilitates executive attention by detecting conflicts arising from incompatible information processing streams (Hölzel, Lazar, et al., 2011; van Veen & Carter, 2002). It has been proposed that in the presence of distractors during mindfulness, ACC activation may facilitate systems involved in the top-down regulation of cognitive control (van Veen & Carter, 2002) and form a network with the fronto-insular cortex that supports shifts in activation of different networks, thereby facilitating responses to cognitively challenging events (Sridharan, Levitin, & Menon, 2008).

Neuroscientific research has demonstrated that meditation is associated with greater activation in frontal regions implicated within attentional control, such as the dorsolateral PFC (Brefczynski-Lewis et al., 2007; Cahn & Polich, 2006; Short et al., 2010) and the ACC (Cahn & Polich, 2006; Gard et al., 2010; Hölzel et al., 2007; Short et al., 2010; Tang et al., 2009). Tang et al. (2009) found that a 5-day Integrative Body-Mind Training (IBMT) incorporating FA practice led to increased activation of the ACC during resting state compared to a divided attention control condition. Interestingly, Brefczynski-Lewis et al. (2007) found an inverted u-shaped curve in which experienced practitioners with an average of 19,000 hours of practice showed similar activation patterns to novices within regions underlying attentional networks. However, experienced practitioners with an average of 44,000 hours of meditation experience showed less activation in the same brain regions. These findings suggest that increased attentional control may be associated with greater ACC activation and that extended meditation practice may result in a smaller magnitude of effort required to monitor conflicts (Hölzel, Lazar, et al., 2011). Moreover, Brefczynski-Lewis et al. also found increased stability in the amygdala response to a negative distraction during FA, which was positively correlated with meditation experience. Relatedly, van den Hurk, Janseen, Giommi, Barendregt, and Gielen (2010) found that trait mindfulness was associated with changes in bottom-up processing and an improved allocation of attentional resources across visual and auditory modalities. Results demonstrated the reduced interference of a visual warning stimulus and attenuated intersensory facilitation (reduced RT to the rapid presentation of stimuli in two different modalities), in experienced meditators using a variation of the spatial cueing paradigm.

Enhanced ACC activation has also been observed following mindfulness practice. Zeidan et al. (2011) indicated that focused mindfulness was associated with increased activity in the ACC and insula, which reflected improved attentional control and the reduced subjective experience of pain intensity in the presence of noxious stimulation. A functional connectivity MRI (fcMRI) study demonstrated that MBSR was associated with (i) greater connectivity between areas associated with attentional processing (dorsomedial PFC) and the attended sensory cortex and (ii) increased connectivity within sensory networks during a period that participants were mindful of environmental sounds (Kilpatrick et al., 2011). Participants also showed greater differentiation between (i) regions of the ACC and the unattended sensory cortex and (ii) attended and unattended sensory networks. These findings support that mindfulness is associated with improved executive attention and sensory processing, in accordance with hypotheses that greater differentiation between networks reflects processing efficiency (Deco, Jirsa, McIntosh, Sporns, & Kotter, 2009; Kelly, Uddin, Biswal, Castellanos, & Milham, 2008; Lewis, Baldassarre, Committeri, Romani, & Corbetta, 2009). Structural MRI findings have similarly indicated that mindfulness exerts effects on the ACC, and therefore, executive attention. Research has found increased cortical thickness of gray matter in the ACC in meditators (Grant, Courtemanche, Duerden, Duncan, & Rainville, 2010) and white matter integrity in the ACC following 11 hours of IBMT (Tang et al., 2010).

In contrast to this converging evidence, a small proportion of research has not found associations between enhanced attentional control and mindfulness (Anderson et al., 2007; Polak, 2009; Semple, 2010) and meditation (Josefsson & Broberg, 2011).

4.4 Attention Switching

Evidence of the effects of mindfulness and meditation on attention switching capabilities is mixed. A brief mindfulness retreat (Chambers et al., 2008) and 8 week MBSR (Anderson et al., 2007) and MBCT (Heeren, van Broeck, & Philippot, 2009) interventions were not associated with improved attention switching capabilities. However, Hodgins and Adair (2010) found that experienced meditators identified more alternative perspectives of ambiguous images and more quickly identified the first person perspective during the Ambiguous Image Perspective-Switching task. These contrasting results have led to hypotheses that (i) attention switching results from long-term practice (Chiesa, Calati, & Serretti, 2011; Hodgins & Adair, 2010) or (ii) attention switching is resistant to the benefits of mindfulness (Cusen et al., 2010).

4.5 Further Attentional Abilities

Preliminary evidence supports associations between meditation and a reduced attentional blink representative of widespread attentional processing. Meditators who had participated in a 3-month Vipassanā retreat demonstrated a significantly reduced attentional blink, as measured by performance on computerised tasks (Slagter et al., 2007; Slagter, Lutz, Greischar, Nieuwenhuis, & Davidson, 2009). Slagter et al. (2007) also found that reductions in attentional blink size were associated with decreased resource allocation to the first target as reflected by EEG data of smaller p3b amplitudes elicited by target 1. Moreover, Slagter et al. (2009) found that meditation was associated with reduced cross-trial variability in the phase of oscillatory theta activity following the acknowledgement of target 2, particularly for individuals who demonstrated largest reductions in resource allocation to target 1. This suggests improved attentional processing and the increased availability of cognitive resources following meditation. van Leeuwen, Muller, and Melloni (2009) similarly found that an attentional blink in experienced meditators was smaller in magnitude compared to both age-matched and younger controls, despite evidence that performance on the attentional blink reduces with age (Chiesa & Serretti, 2010).

The effect of meditation on change blindness is less clear. Whilst some have found non-significant effects (Anderson et al., 2007; McMillan et al., 2002), Hodgins and Adair (2010) found that meditators noticed significantly more changes in flickering scenes on the Change Blindness Flickering Task and that they did so more quickly than non-meditators. Collectively these findings may preliminarily reflect improved attentional processing following meditation; meditators may have more available cognitive resources and so may be able to process new stimuli more quickly following meditation.

4.6 Differences Between Meditation and Mindfulness Styles

No studies have directly compared different mindfulness practices and few have compared FA and OM within a single design. Additionally, conclusions are constrained by significant variation within meditation samples and the inclusion of both FA and OM meditators within the same sample (e.g., Josefsson & Broberg, 2011; Kozasa et al., 2012; Pagnoni & Cekic, 2007; Short et al., 2010; van den Hurk, Giommi, et al., 2010; van Leeuwen et al., 2009). Others have provided few details of the meditation traditions examined within their studies (e.g., Hodgins & Adair, 2010). However, there is some preliminary evidence for differential effects of distinct meditation styles.

Generally, the evidence-base suggests that extended FA practice is most often associated with improved alerting (e.g., Brefczynski-Lewis et al., 2007; Carter et al., 2005; Lazar et al., 2000; MacLean et al., 2010; Tang et al., 2010). Both improved orienting (Brefczynski-Lewis et al., 2007; Chan & Woollacott, 2007) and executive attention (e.g., Tang et al., 2007; Tang et al., 2009; Wenk-Sormaz, 2005) have also been associated with FA.

OM practitioners and experienced meditators also demonstrate improved attentional abilities within these domains compared to control participants (Chan & Woollacott, 2007; Hodgins & Adair, 2010; Moore & Malinowski, 2009; Pagnoni & Cekic, 2007; Valentine & Sweet, 1999; van den Hurk, Giommi et al., 2010). Moreover, positive correlations have been found between meditative experience and improved attention, as indicated by neuropsychological data (e.g., Chan & Woollacott, 2007; Valentine & Sweet, 1999) and neuroscientific evidence of functional and structural changes (e.g., Grant et al., 2010; Hölzel et al., 2007; Pagnoni & Cekic, 2007). Extensive meditation practice representative of OM appears to largely involve structures involved in improved attentional control, greater cognitive resources (Brefczynski-Lewis et al., 2007; Lutz, Slagter et al., 2008; Raffone & Srinivasan, 2010; Slagter et al., 2007; Valentine & Sweet, 1999; van den Hurk, Janseen, et al., 2010; van Leeuwen et al., 2009) and perhaps enhanced attention switching (Hodgins & Adair, 2010). These findings are supported by Manna et al.'s (2010) fMRI comparison of the neural correlates of FA and OM in experienced meditators and novice practitioners. They found positive correlations between meditation experience and deactivations in the right inferior frontal gyrus (implicated within cognitive control) and the insula, indicative of a more effortless maintenance of attentional control in experienced meditators. Moreover, OM was characterised by a lateral prefrontal activation in both hemispheres similar to a resting state, with a subtle enhanced (predominantly left) medial frontal activation, compared to rest. In contrast, FA was significantly differentiated from resting state, with enhanced (predominantly right) medial frontal and reduced (predominantly left) lateral prefrontal activation. These findings support distinctions between FA and OM and highlight that OM is associated with increased cognitive control and reserves.

The evidence-base preliminarily suggests that even brief mindfulness practice can improve alerting (Semple, 2010; Zeidan, Johnson, Diamond, et al., 2010) and particularly orienting (Friese et al., 2012; Jensen et al., 2011; Jha et al., 2007; Kerr et al., 2011; Lakey et al., 2010) and executive attention (Jha et al., 2007; Kilpatrick et al., 2011; Zeidan et al., 2011). It is hypothesised that orienting and executive attention abilities develop early during mindfulness (e.g., Hölzel, Lazar, et al., 2011). This is supported by evidence that whilst the performance of experienced meditators is superior to controls, there are non-significant differences between expert and novice practitioners on measures of orienting (Brefczynski-Lewis et al., 2007; Jha et al., 2007) and executive attention (Brefczynski-Lewis et al., 2007). Moreover, direct comparisons have found non-significant differences between FA and OM within domains of executive attention (Chan & Woollacott, 2007). It is not currently possible to comment on distinctions between focused and open mindfulness since (i) there has been no direct comparison and (ii) open mindfulness has only been examined within the context of programmes such as MBSR or MBCT. However, inferences from the meditation literature suggest that differences between these mindfulness practices may exist.

4.7 Summary

The evidence that meditation and mindfulness are associated with widespread attentional improvements is robust. These findings are consistent with contemporary perspectives of attention as a key mindfulness mechanism and suggestions that the benefits of mindfulness are exerted through the top-down regulation of an array of interrelated components. The literature also preliminarily suggests that FA and OM may exert differential effects, intimating that differences between distinct mindfulness styles warrant further research.

5.0 The Role of Attention in the Development and Maintenance of Anxiety

Theoretical conceptualisations and empirical evidence suggest that common psychological processes are involved in the development and maintenance of different anxiety disorders (e.g., Mathews & Macleod, 2005). Whilst these processes have largely been considered in the context of trait anxiety, such debates are relevant to clinical anxiety since (i) trait anxiety predisposes clinical anxiety (Barlow, 2002) and (ii) the degree of attentional bias within high trait anxious (HTA) and clinically anxious individuals is similar (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorn, 2007).

An attentional bias towards threat describes increased attentional allocation to threat stimuli compared to neutral stimuli. Attentional biases towards aversive stimuli are commonly found in anxious individuals (d = .45) but are less apparent or non-existent in non-anxious people (Bar-Haim et al., 2007). These biases are observed to the same degree in a range of anxiety disorders (Bar-Haim et al., 2007), including GAD (e.g., McNamara & Hajcak, 2010; Mogg & Bradley, 2005), social phobia (e.g., Becker, Rinck, Margraf, & Roth, 2001), post-traumatic stress disorder (e.g., Bryant & Harvey, 1997), specific phobia (e.g. Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005), panic disorder (e.g., Buckley, Blanchard, & Hickling, 2002) and obsessive compulsive disorder (e.g., Amir, Najmi, & Morrison, 2009).

5.1 Components of Attentional Biases in Anxiety

Research indicates that attentional biases in anxiety include facilitated attention to threat, delayed disengagement from threat stimuli and an attentional avoidance of aversive information. Studies have demonstrated these biases using various paradigms, suggesting that the effects are not due to methodological design or task confounds (Cisler & Koster, 2010). These biases seem to be exacerbated by pervasive attentional control deficits associated with anxiety disorders.

5.1.1 Facilitated attention/hypervigilance to threat. Facilitated attention/hypervigilance to threat reflects that attention is directed more quickly to aversive information (Cisler & Koster, 2010). Whilst some research employing the Spatial Cueing Task has not found facilitated attention to threat in anxious individuals (Amir, Elias, Klumpp, & Przeworski, 2003; Fox et al., 2001; Yiend & Matthews, 2001), others have found that a short stimulus duration (100ms or less) facilitates attention in anxious participants (Carlson & Reinke, 2008; Koster, Crombez, Verschuere, van Damme, & Wiersema, 2006). Research using classical conditioning paradigms has also found facilitated attention to threat using the same measure when neutral stimuli are paired with aversive stimuli, such as loud noise bursts (e.g. Cisler & Koster, 2010; van Damme, Crombez, Hermans, Koster, & Eccleston, 2006). Facilitated attention has also been evidenced using visual search methodologies (e.g., Gilboa-Schechtman, Foa, & Amir, 1999; Miltner, Krieschel, Hecht, Tripp, & Weiss, 2004; Rinck et al., 2003, experiment 2; Rinck et al., 2005, experiments 2 and 3; Weinberg & Hajcak, 2011).

5.1.2 Delayed disengagement from threat. A difficulty disengaging attention from threat reflects the degree to which a threat cue holds attention and disrupts attention switching to other stimuli (Cisler & Koster, 2010). With few exceptions (Carlson & Reinke, 2008; Pflugshaupt et al., 2005), research suggests that anxious individuals experience a difficulty disengaging from consciously presented threat stimuli. These findings have been evidenced using the Spatial Cueing Task (e.g., Amir et al., 2003; Cisler & Olatunji, 2010; Fox et al., 2001; Koster, Crombez, Verschuere, van Damme, et al., 2006; Yiend & Mathews, 2001). The reliability and validity of this paradigm as an index of delayed disengagement has been challenged since it is possible that a generic slow down caused by presentation of threat effect could confound its measurement of this construct (Mogg, Holmes, Garner, & Bradley, 2008). However, findings have been replicated using other experimental paradigms, including visual search paradigms (e.g., Gilboa-Schechtman et al., 1999; Lipp & Waters, 2007; Miltner et al., 2004; Rinck et al., 2003; Rinck et al., 2005) and the Dot Probe Task (e.g., Koster, Crombez, Verschuere, & De Houwer, 2006; Salemink, van den Hout, & Kindt, 2007).

5.1.3 Attentional avoidance. Attentional avoidance refers to the avoidance of threat via preferential allocation of attention away from threat stimuli (Cisler & Koster, 2010). This phenomenon has been observed in anxious individuals at long stimulus durations using the Dot Probe Task (Garner, Mogg, & Bradley, 2006; Mogg, Bradley, Miles, & Dixon, 2004) and eye-movement paradigms (Calvo & Avero, 2003; Pflugshaupt et al., 2005; Rohner, 2002).

5.2 Mechanisms of Attentional Biases in Anxiety

Neurocognitive models of anxiety posit the role of amygdala-prefrontal circuitry as neural mechanisms underlying attentional biases in anxiety disorders (Bishop, 2007; Bishop, 2008; Davidson, 2002; Davis & Whalen, 2001). Neurobiological findings consistently highlight that the amygdala is involved in facilitated attention to threat (Anderson & Phelps, 2001; Bishop, Duncan, Brett, & Lawrence, 2004; Carlson, Reinke & Habib, 2009; Monk et al., 2004; Nitschke et al., 2009; Stein, Simmons, Feinstein, & Paulus, 2007; van den Heuvel et al., 2005) but does not operate completely automatically and is dependent on available attentional resources (Pessoa, 2005). Neuroimaging has demonstrated that dysfunction within the lateral PFC and its functionally-related structures, such as the ACC, is associated with threat processing (Bishop, Duncan, et al., 2004; Browning, Holmes, Murphy, Goodwin, & Harmer, 2010). Moreover, state anxiety has been inversely correlated with PFC activation (r = -.60) during threat processing (Bishop, Duncan, et al., 2004) whilst trait anxiety has been inversely correlated with poorer structural integrity of amygdala-prefrontal pathways (Kim & Whalen, 2009).

There has been little theoretical convergence between cognitive models of anxiety; models have ascribed differences pertaining to stage of processing at which attentional biases occur and the automatic and strategic mechanisms underlying these. However, attentional control theory (Eysenck, Derakshan, Santos, & Calvo, 2007) offers a contemporary framework of the current evidence-base and is consistent with neurocognitive models of anxiety. Attentional control theory proposes that anxiety disrupts the relationship between bottom-up sensory mechanisms sensitive to stimulus salience and top-down control mechanisms that support processing and attentional regulation (Derakshan & Eysenck, 2009; Eysenck et al., 2007). Anxiety is suggested to (i) impair top-down control by attenuating the magnitude to which inhibitory processes regulate automatic responses and (ii) increase bottom-up processing, resulting in facilitated attention of and delayed disengagement from threat in HTA individuals.

Concordantly, research has associated anxiety with impaired attentional control. Consistent with postulations of attentional control theory (Eysenck et al., 2007), research indicates that aversive but task-irrelevant information is more intrusive in HTA individuals (Bar-Haim et al., 2007). Evidence also suggests that anxiety is associated with impairments in inhibitory control and set-shifting (e.g., Ansari, Derakshan, & Richards, 2008; Derakshan & Eysenck, 2009; Wieser, Pauli, & Műhlberger, 2009). Additionally, anxiety has been found to affect processing efficiency more than effectiveness (e.g., Derakshan, Ansari, Hansard, Shoker, & Eysenck, 2009). Moreover, preliminary research indicates that attentional control capabilities explicitly mediate delayed disengagement from aversive stimuli in anxious individuals (Derryberry & Reed, 2002) and non-clinical populations (Peers & Lawrence, 2009).

Attentional avoidance has been implicated within various cognitive models of anxiety and is generally thought to reflect attempts to strategically regulate negative affect (e.g., Cisler & Koster, 2010; Mogg & Bradley, 1998; Mogg, Bradley, De Bono, & Painter, 1997; Wells & Matthews, 1994; Williams, Watts, MacLeod, & Mathews, 1997). Furthermore, poor attentional control is hypothesised to contribute to attentional avoidance in anxious individuals through its down-regulation of subcortical emotional systems and interactions with emotion regulation strategies (e.g., Cisler & Koster, 2010). Accordingly, preliminary research indicates that emotion regulation goals moderate components of attentional biases at late states of processing and that attentional avoidance can regulate emotion (Dunning & Hajcak, 2009; Johnson, 2009).

Some evidence also suggests that HTA individuals compensate for attenuated attentional control in their allocation of additional neurocognitive resources (Ansari & Derakshan, 2011; Basten, Stelzel, & Fiebach, 2011), particularly when previously exposed to a highly demanding cognitive event (Osinsky, Alexander, Gebhardt, & Hennig, 2010). These findings preliminarily support recent theoretical propositions that HTA individuals differ in the way that they exert top-down regulation; HTA individuals are hypothesised to employ neurocognitive resources in a reactive rather than a sustained manner, characteristic of low trait anxious individuals (Braver, Gray, & Burgess, 2007). Discrepancies in methodological design and the temporal analysis of cognitive control may therefore account for studies that have not found associations between anxiety and greater recruitment of neural mechanisms (Bishop, 2009; Bishop, Duncan, et al., 2004; Klumpp et al., 2011).

5.3 Summary

The evidence-base suggests similarities between neurobiological and neuropsychological components that underlie anxiety disorders but are enhanced by meditation and mindfulness. Mindfulness may improve attentional capabilities and higher-order control mechanisms, reflected by neuroplastic changes within frontal cortical structures such as the PFC, its subunits and functionally-related structures (e.g., ACC) that down-regulate subcortical regions. In contrast, anxiety is associated with dysfunction within amygdala-prefrontal pathways, reflected in impaired top-down attentional control and increased bottom-up processing. Moreover, there is some preliminary evidence that mindfulness facilitates the availability of cognitive reserves that are depleted in anxious individuals. This highlights the role of mindfulness in the treatment of anxiety through attentional mechanisms.

6.0 The Role of Attentional Training and Mindfulness in the Treatment of Anxiety

In recent years, attentional training, including cognitive bias modification (CBM) has been developed to modify attentional biases in anxious individuals. CBM usually involves computerised visual probe training tasks in which participants are required to repeatedly practice directing their attention to the opposite location to aversive stimuli (MacLeod & Holmes, 2012). Attentional training has been associated with improved attention and reduced anxiety in clinical and subclinical groups (e.g., Amir, Beard, Cobb, & Bomyea, 2009; Amir, Najmi, et al., 2009; Chen et al., 2011; Hazen, Vasey, & Schmidt, 2009; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002; Schmidt, Richey, Buckner, & Timpano, 2009). Some research suggests that gains are maintained after 4 months (Schmidt et al., 2009). Initial evidence also suggests that training effects can be transferred to non-trained contexts (Amir, Beard, et al., 2009; Chen et al., 2011; Macleod et al., 2002; Schweizer, Hampshire, & Dalgleish, 2011).

A small number of studies have directly examined the effect of mindfulness on attentional biases that confer vulnerability to anxiety. Improved disengagement to threat at later stages of processing (400-500ms) was found following 7 weeks of focused mindfulness (Ortner, Kilner, & Zelazo, 2007) and mindfulness-based interventions (combined focused and open mindfulness) of 10 sessions (Garland, Gaylord, Boettiger, & Howard, 2010) and 8 weeks (Vago & Nakamura, 2011). Vago and Nakamura (2011) additionally found reduced avoidance of pain-related threat at early stages of processing (100ms) amongst individuals with fibromyalgia. Further replications are required within other populations and larger samples.

7.0 Critique of the Evidence-Base

7.1 Conceptualisations of Mindfulness and Cognitive Function

Despite efforts to universally operationalize mindfulness (e.g., Bishop, Lau, et al., 2004), there has been limited consensus, with mindfulness variously conceptualised as a process, transient mental state or stable, dispositional trait (Davidson, 2010). Mechanisms of action, attentional processes and affective outcomes may not be the same in these contexts. Mindfulness as a unitary or multiple construct has also been contentious, as reflected within measures that have encompassed between one (e.g., Brown & Ryan, 2003) and five (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006) facets of mindfulness.

Similarly, although the localisation of cognitive functions continues to be useful, it is important to acknowledge connections between cognitive domains. Associations between neurological mechanisms, behavioural phenomenology and affective symptomatology importantly contribute to our understanding of mindfulness mechanisms. However, a reductionist focus on associations between very specific components does not reflect our understanding of complex and non-linear interactions between these domains and may cause generic self-regulatory processes to be mistaken for specific neurological mechanisms with associated cognitive and behavioural correlates (DiClemente, 2010). Therefore, their categorisation as independent abilities may reflect heuristic as opposed to objective distinctions. Moreover, there has been significant overlap within the literature regarding those constructs associated with particular mechanisms of mindfulness.

7.2 Methodological Limitations

7.2.1 Study design. The evidence-base is heavily influenced by methodological constraints, including non-randomisation, the absence of single or double-blind designs, differential attrition rates across conditions and small sample sizes, particularly in the case of neuroimaging research. Only two small meditation trials of moderate quality that reported contrasting findings were deemed eligible for inclusion in the most recent Cochrane Collaboration review of the effects of mindfulness and meditation on anxiety (Krisanaprakornkit et al., 2009). Meta-analyses have also included a small number of studies and less rigorous methodologies (e.g., Baer, 2003; Grossman et al., 2004; Hofmann et al., 2010). Furthermore, few have examined clinically significant change or broader ranges of outcome, such as quality of life.

Positive findings have most often been observed in cross-sectional case-control studies. Possible confounds include baseline differences regarding psychological, cultural and/or religious characteristics among practitioners. Associations between long-term mindfulness practice and health and personality difference arising from lifestyle changes may also bias findings (Rubia, 2009). Moreover, it is possible that self-selection and motivational biases may be particularly prevalent within experienced meditators who are heavily invested in the tradition. Preliminary evidence suggests that task effort and compliance is important (Jensen et al., 2011) and whilst some have assessed these (e.g., Wenk-Sormaz, 2005), few have directly manipulated these domains. Non-significant associations between meditative or mindfulness experience and outcome could reflect these baseline variances (Slagter et al., 2007).

A significant proportion of research has been uncontrolled and thus has not accounted for progression through time, placebo effects or demand characteristics. Other researchers have employed wait-list controls (e.g., Anderson et al., 2007) or treatments as usual that have comprised of medical interventions or unspecified mental health approaches that are structurally different (e.g., Cusen et al., 2010). It has been difficult to evaluate the integrity of both active control conditions and mindfulness interventions since instructor experience is not usually well described and few have evaluated the delivery of the intervention. Where reported, the duration of mindfulness, instructor qualities and participant instructions have varied considerably. Similarly, neuroimaging studies have used various control tasks, such as arithmetic (Hölzel et al., 2007), that differ from mindfulness in level of stimulation, cognitive demand and response preparation (Rubia, 2009).

7.2.2 Heterogeneity within mindfulness practice. Reflecting discrepancies in the conceptualisation and operationalization of mindfulness, significant heterogeneity exists between practices subsumed under the overarching term of ‘mindfulness’. Significant differences in style and experience are often found within studies of long-term practitioners, with details of meditative style not always specified. Subtle differences between the qualities emphasised within different practices, such as compassion, self-control, emotion regulation and focused attention, may be associated with different neural, cognitive and behavioural correlates (Dorjee, 2010; Rubia, 2009). Moreover, discriminations between FA and OM have been difficult since many studies have examined Zen/Vipassanā meditators whom have combined FA and OM practices. Furthermore, long-term practitioners may inadvertently use strategies more consistent with OM than FA when engaged in a focused attention task due to their improved receptive awareness and attentional abilities (Lutz, Brefczynski-Lewis et al., 2008; Manna et al., 2010). Caution is required when interpreting neuroimaging data of resting states for this reason (Cahn et al., 2010). Additionally, there is often wide variation in the experience of meditators included within these studies (e.g., Brown & Jones, 2010; Cahn et al., 2010; van den

Hurk, Giommi, et al., 2010). These constraints may explain some discrepancies within the literature. For example, interpretations of non-significant findings by Josefsson and Broberg (2011) were constrained by their examination of meditators from heterogeneous traditions and with meditative experience ranging from 1-180 months.

Examination of the effects of mindfulness within interventions such as MBSR, MBCT, IMBT and intensive retreats on naïve or novice participants has also been problematic due to the integration of additional components, such as relaxation and cognitive restructuring (e.g., MBSR and MBCT), guided imagery and music therapy (e.g., IBMT) and yoga (e.g., retreats and some MBSR programmes). These interventions are distinct but partially overlaying applications of mindfulness. Consequently, comparisons between them have limited validity. It is also difficult to differentiate between the effects of attentional components from other mechanisms and it is possible that different mechanisms become more or less relevant depending on the context (Dorjee, 2010). Moreover, similar effects may be achieved through different mechanisms.

7.2.3 Paradigms of mindfulness and attention. Contrasting results observed within the literature may also be due to the divergent methodologies used to explore the role of attention within anxiety and as a mechanism of mindfulness (Moore & Malinowski, 2009; Olatunji, Ciesielski, Armstrong, Zhao, & Zald, 2011). A wide variety of paradigms have been employed that may differentially assess attentional subsets or may measure them non-independently from other attentional components or cognitive functions. For example, Heeren et al. (2009) utilised the Trail Making Test (Lezak, 1995) that reflects multiple cognitive functions as a measure of attention switching. It is also possible that null findings obtained by McMillan et al. (2002)

may be partly attributed to their use of the Trail Making Test, Test of Everyday Attention (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994) and the Paced Auditory Serial-Addition Test (Gronwall, 1977), which have been infrequently used by other researchers to measure the effects of mindfulness and anxiety on attentional components. Additionally, it has been argued that variants of the Stroop task principally measure response selection and fail to generalise to other attentional mechanisms (e.g., Baldo, Shimamura, & Prinzmetal, 1998). Some have also observed ceiling effects using this measure (Kozasa et al., 2012). The possibility of practice effects has been observed within tests of attentional blink and the conflict monitoring task of the ANT. Moreover, the Object Detection Task employed by Anderson et al. (2007) lacks validity and reliability indices. Greater consistency between the paradigms utilised to operationalize the concept of mindfulness is also important to ensure consistency, validity and generalisation.

Some propose that the insensitivity of current psychological paradigms to detect changes following mindfulness practice may account for inconsistencies between findings (Davidson, 2010). It has also been suggested that participants may not be able to reliably report on the quality and degree of their mindfulness (Coffey et al., 2010; Grossman, 2011) and that dispositional mindfulness of novice practitioners is better conceptualised as state mindfulness (Schmertz, Anderson & Robins, 2009).

8.0 Future Directions

A universal and unequivocal operationalization of mindfulness and its external referents (Grossman 2011) and further exploration of mindfulness varieties will be important to ensure comparisons amongst the same styles and components of mindfulness. Moreover, compatibility between researchers' conceptualisations of mindfulness and their operationalization of the construct within their methodologies should be ensured (Davidson, 2010). It is currently unclear how the validation of self-report mindfulness measures should progress. One possibility is the examination of associations between self-report measures and behavioural, electrophysiological and hemodynamic correlates of the opposing construct of mind-wandering, which describes shifts of attention resulting in task failures and inattentive representations of the external environment (e.g., Davidson, 2010; Mrazek, Smallwood, & Schooler, 2012).

It is important that case-controlled data continues to be supplemented with RCTs involving novice practitioners and matched control groups, since they are likely to differ from long-term meditators with regards to personality and affective characteristics, expertise and mindfulness techniques cultivated. Control conditions should be structurally similar and include participants matched on specific and non-specific factors associated with change, such as confidence in the intervention, positive expectations and instructor qualities (e.g., Baskin, Tierney, Minami, & Wampold, 2003). This will contribute to our understanding of specific and non-specific effects of mindfulness and its mechanisms.

Whilst case control studies demonstrate long-term attentional benefits of meditation, research assessing the impact of mindfulness of varying durations is required using follow-up studies or longitudinal designs (Chiesa & Serretti, 2010).

This is important since many participants continue to practice mindfulness (Miller, Fletcher, & Kabat-Zinn, 1995) and there is some initial evidence of the long-term positive effects of mindfulness on anxiety and affect (e.g., Hofmann et al., 2010; Mathew, Whitford, Kenny, & Denson, 2010). It will be important to understand the impact of mindfulness on both state and trait attributes, to exclude placebo-effects (Cahn & Polich, 2006) and to link neurobiological changes with trait clinical changes. Some research suggests that the involvement of different attentional domains may be moderated by experience (Brefczynski-Lewis et al., 2007), emphasising the need for further research attention within this area.

Research indicates that very brief mindfulness interventions and FA inductions (10 minutes to 4 sessions) can improve attentional components (e.g., Arch & Craske, 2006; Lakey et al., 2010; Wenk-Sormaz, 2005; Zeidan, Johnson, Diamond, et al., 2010; Zeidan et al., 2011) and anxiety (Jain et al., 2007; Zeidan, Johnson, Diamond, et al., 2010). Minimal and optimal doses required to achieve beneficial attentional and affective outcomes requires confirmation. This will be important for the viable integration of mindfulness interventions within the National Health Service that are time-efficient and cost-effective.

Dismantling designs and mediational analyses will be important to examine the differential efficacy of mindfulness components. A greater understanding of the mechanisms of mindfulness and differences between variants will (i) facilitate an understanding of those components cultivated through different techniques, (ii) determine the relevance of specific mindfulness mechanisms within different contexts and (iii) enable the assessment of the differential effectiveness of distinct mindfulness practices. There are no comparisons between focused and open mindfulness and direct comparisons between FA and OM are scarce. Additionally, few have compared meditation and mindfulness styles with different foci, such as internal cognitive or emotional stimuli, physiological sensations or varying external stimuli. Direct comparisons employing reliable and valid paradigms to investigate the specificity of cognitive, affective and neurobiological change associated with these varieties will be useful (Rubia, 2009).

Few studies have assessed associations between mindfulness and attention within clinically anxious populations. The inhalation of 7.5% carbon dioxide (CO_2) in healthy volunteers has more recently been introduced within experimental settings to provide a putative experimental model of GAD. Inhalation of 7.5% CO_2 has been associated with self-reported levels of anxiety and autonomic arousal (Bailey, Papadopoulos, Seddon, & Knutt, 2009) and has induced neurocognitive dysfunction characteristic of GAD, including facilitated attention to and delayed disengagement from threat (Bailey et al., 2011; Garner, Attwood, Baldwin, James, & Munafò, 2011). This paradigm could be used in combination with reliable attentional measures and self-report measures of anxiety to examine the impact of mindfulness practice on (i) subjective and autonomic aspects of anxiety and (ii) induced attentional bias.

9.0 Conclusion

Mechanisms of mindfulness are receiving growing attention. Evidence suggests that mindfulness is associated with improved attentional abilities, particularly within domains of alerting, orienting and executive attention. Although inherent theoretical, conceptual and methodological limitations require further research, these findings are robust. Converging evidence has demonstrated positive correlations between mindfulness practice and (i) enhanced attentional performance and (ii) structural and functional changes underlying these attention networks. Moreover, some evidence suggests that long-term meditation is associated with functional changes related to attention networks even when meditation is not being practiced (Jang et al., 2011; Kozasa et al., 2012). There is some preliminary evidence that FA and OM differentially affect attentional components; whilst both facilitate enhanced alerting, orienting and executive attention, FA is most consistently associated with improved alerting and extended practice akin to OM is most often associated with improved attentional control and cognitive resources. These findings highlight the need to further explore differential effects of distinct mindfulness practices.

The evidence-base supports contemporary theoretical and conceptual accounts that salutary effects of mindfulness are achieved through specific effects and highlights that attentional components may represent one of several distinct but interrelated mechanisms that work synergistically. Findings also suggest that attentional changes occur during early stages of mindfulness practice, in accordance with hypotheses that attention may be a prerequisite for other mechanisms to exert their effects. Some models propose an upward spiral process in which mindfulness mechanisms mutually facilitate one another (e.g., Garland et al., 2011; Hölzel, Lazar, et al., 2011). For example, attentional improvements following mindfulness could improve self-focused awareness through enhanced attention to internal experiences, which in turn promotes emotion identification and initiates the employment of emotion regulation strategies (Hölzel, Lazar, et al., 2011). Improved emotion regulation may also be developed through greater top-down attentional control over affective stimuli, facilitated by enhanced activation of frontal cortical regions to abate amygdala hyperactivity to threat (Brefczynski-Lewis et al., 2007; Chiesa & Serretti, 2010; Creswell et al., 2007; Rubia, 2009). The non-judgemental, observer quality of mindfulness may further enhance acceptance and meta-cognitive shifts and could substitute narrative forms of self-reference (Carmody, 2009; Hölzel, Lazar, et al., 2011). In turn, meta-cognitive shifts may also effect more adaptive reappraisals of events which could encourage further improved attentional regulation (Grabrovac et al., 2011; Hölzel, Lazar, et al., 2011). Attentional improvements following mindfulness practice could also mediate relaxation and improve mind-body function; research indicates close associations between improved function in structures that underlie the attention network and autonomic function (Kubota et al., 2001; Newberg et al., 2010). Further research is required to test these hypotheses of the interactions between mechanisms of mindfulness.

Very little research has addressed the efficacy of mindfulness training to attenuate attentional biases in anxiety disorders. Attentional biases, comprised of facilitated attention to and delayed disengagement from threat and attentional avoidance of aversive stimuli, partially mediated by attentional control capacities, are implicated within theoretical models of anxiety and consistently evidenced within experimental psychopathological research. The evidence-base indicates that neurobiological and neuropsychological processes implicated in emotion dysregulation are conversely improved following mindfulness and meditation. Anxiety disorders are associated with maladaptive amygdala-prefrontal pathways and impaired attentional control. In contrast, meditation and mindfulness are associated with enhanced attentional capabilities and neuroplasticity in prefrontal areas and functionally related structures implicated in attentional control and higher-order control mechanisms. Moreover, the neurobiological basis of mindfulness is similar to other effective treatments of anxiety, including psychotherapy (Chiesa & Serretti, 2010). Preliminary research suggests that attentional training, such as CBM, is efficacious in the treatment of anxiety and that mindfulness applications can directly attenuate attentional biases that confer vulnerability to anxiety disorders. Moreover, preliminary research indicates the prophylactic effects of mindfulness; mindfulness is associated with cognitive reserves that can be deployed to guard against impairment in challenging contexts (Friese et al., 2012; Manna et al., 2010). These converging lines of evidence, in combination with evidence of the beneficial effects of mindfulness for anxiety, suggest that mindfulness could be valuable in the prevention as well as intervention of anxiety disorders and that attentional improvements may predominantly mediate these effects.

Further research in a number of directions using innovative research paradigms, such as the CO_2 challenge, will be important to improve our understanding of the mechanisms of mindfulness. A greater understanding of mindfulness mechanisms will be important to verify current conclusions, establish the specificity and generalisability of mindfulness and promote the applicability of mindfulness in the treatment of anxious symptomatology that continues to be prevalent, pervasive and associated with a range of negative outcomes.

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Empirical Paper

Prophylactic Effects of Mindfulness: The Effects of Focused and Open Mindfulness Inductions on CO_2-Induced Anxiety

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ABSTRACT

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PROPHYLACTIC EFFECTS OF MINDFULNESS: THE EFFECTS OF FOCUSED AND OPEN MINDFULNESS INDUCTIONS ON CO_2-INDUCED ANXIETY

by Jemma Emily Marshall

This study examined the prophylactic and differential effects of brief mindfulness practice on heightened anxiety and negative affect, as induced through the inhalation of 7.5% carbon dioxide (CO_2). 60 participants were randomised to a focused mindfulness induction (FM), open mindfulness induction (OMi) or relaxation control condition prior to 7.5% CO_2 and air inhalation. Subjective measures of state anxiety and affect and physiological measures of blood pressure and heart rate were collected at baseline and following mindfulness. Mixed-design analyses of variance with group (FM, OMi, control) and inhalation (CO_2 vs. air) as independent variables were used to examine the effects of mindfulness and relaxation on subjective and autonomic responses to CO_2. All groups experienced heightened state anxiety and negative affect following inhalation of CO_2 compared to air (ps < .01), thereby providing further empirical validation of the 7.5% CO_2 challenge within healthy volunteers as a novel and putative experimental model of generalised anxiety disorder. However, FM and OMi practice was significantly associated with similar reductions in subjective state anxiety and negative affect, compared to relaxation (ps < .05). In the context of non-significant reductions in autonomic measures of arousal, these findings are consistent with conceptualisations that mindfulness exerts its benefits through specific effects and top-down mechanisms that support emotion regulation. This study replicates and extends previous findings of the beneficial effects of mindfulness and highlights the propensity for mindfulness to be applied at all levels of a stepped-care approach as an effective treatment for common mental health problems.

Keywords: focused mindfulness, open mindfulness, anxiety, affect

1.0 Prophylactic Effects of Mindfulness on Anxiety

1.1 The Prevalence and Nature of Anxiety

Epidemiological estimates indicate that anxiety disorders continue to be highly prevalent; most recent findings from the Office of National Statistics suggest a one-week and lifetime prevalence of 1.1-4.4% and 1.4-12.1% across England, respectively (McManus, Meltzer, Brugha, Bebbington, & Jenkins, 2009) and a 12-month and lifetime prevalence of 12% and 17-21% across Europe, respectively (Wittchen & Jacobi, 2005). Symptomatology associated with all sub-classes of anxiety disorders has been associated with significant long-term disability (National Institute for Health and Clinical Excellence [NICE], 2011), diminished quality of life (Wittchen & Jacobi, 2005), reduced occupational and social functioning (Maier et al., 2000), co-morbid physical and mental illness (Sareen et al., 2006), morbidity and increased health service utilisation (Krisanaprakornkit, Sriraj, Piyavhatkul, & Laopaiboon, 2009), thereby accruing significant economic burden (Wittchen & Jacobi, 2005).

Current treatment approaches are limited in their ability to reduce anxiety for all individuals. Pharmacotherapy continues to be a first-line treatment approach but is often constrained by the inability of some to tolerate such interventions or their side effects and concerns of escalating prescription rates in the context of uncertain long-term effects of some medications (Kirsch et al., 2008). Moreover, in most cases pharmacotherapies are associated with small-to-medium treatment effects (Hofmann & Mathew, 2008) and relapse in a significant proportion of cases (Butler, Chapman, Forman, & Beck, 2006; Hollon, Stewart & Strunk, 2006). Although psychological interventions, such as cognitive behavioural therapy, continue to be popular, they are often unavailable (NICE, 2011) and associated with persistent residual symptoms

(Durham, Higgins, Chambers, Swan, & Dow, 2011), thus highlighting the need to develop improved interventions. Evidence suggests that mindfulness has the propensity to be an innovative, cost-effective and time-efficient intervention that may improve patients' access to healthcare, in accordance with key priorities for implementation (NICE, 2011) and national imperatives (Department of Health, 2011; The British Psychological Society, 2009).

1.2 Mindfulness and Mindfulness-Based Approaches

Mindfulness derives from Eastern philosophical and meditative practice and describes "paying attention on purpose, in the present moment, and non-judgementally" (Kabat-Zinn, 2003, p. 145), simply observing thoughts, sensations and emotions as they occur. Whilst a universally accepted definition has been hindered by limited conceptual and research consensus, most definitions have emphasised (i) the regulation of attention on the immediate experience and (ii) an orientation of curiosity and acceptance (e.g., Baer, 2003; Bishop, Lau, et al., 2004; Brown & Ryan, 2003; Lutz, Slagter, Dunne, & Davidson, 2008). Whilst the term mindfulness encompasses diverse styles and techniques, practices such as sitting or walking mindfulness have become increasingly popular and incorporated into Western treatment approaches. Mindfulness continues to constitute a core component of interventions such as mindfulness-based stress reduction (MBSR; Kabat-Zinn, 1990), mindfulness-based cognitive therapy (MBCT; Segal, Williams, & Teasdale, 2002), dialectical behaviour therapy (DBT; Linehan, 1993) and acceptance and commitment therapy (ACT; Hayes, Strosahl, & Wilson, 1999)[3].

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[3] Please see the Glossary for further details of these interventions, meditation traditions and neuroanatomical terms.

1.3 The Role of Mindfulness in the Treatment of Anxiety

The widespread beneficial effects of mindfulness for a range of psychological and physical problems have been consistently highlighted within qualitative reviews (Carmody & Baer, 2009; Chiesa & Serretti, 2011; Matchim & Armer, 2007; Ott, Norris, & Bauer-Wu, 2006; Praissman, 2008; Smith, Richardson, Hoffman, & Pilkington, 2005; Teixeira, 2008; Winbush, Gross, & Kreitzer, 2007). In contrast to Toneatto and Nguyen's (2007) small qualitative review that concluded that MBSR does not have reliable effects on anxious and depressive symptomatology, a growing evidence-base generally suggests that mindfulness is associated with medium-to-large treatment effects for anxiety (d = .47-.97; Bohlmeijer, Prenger, Taal, & Cuijpers, 2010; Ledesma & Kumano, 2009; Hedge's g = .63-.97; Hofmann, Sawyer, Witt, & Oh, 2010). Research indicates that the effectiveness of mindfulness is equable across subtypes of anxiety (e.g., Grossman, Niemann, Schmidt, & Walach, 2004; Hofman et al., 2010; Vøllestad, Sivertsen, & Nielsen, 2011). Findings suggest that mindfulness is also efficacious to the same degree in the treatment of depression, which is often co-morbid with anxiety (d = .48-.97; Ledesma, & Kumano, 2009; Hedge's g = .59-.95; Hofmann et al., 2010). Moreover, preliminary evidence suggests that dispositional mindfulness is both negatively correlated with anxiety and depression (Masuda & Tully, 2012) and accounts for unique variance within these presentations (Cash & Whittingham, 2010; Roemner et al., 2009).

Behavioural evidence of the efficacy and effectiveness of mindfulness has been consistently reported using a range of experimental paradigms and questionnaire measures, suggesting that the effect is not due to methodological design or confounds. The benefits of mindfulness have been observed in brief laboratory inductions (Arch & Craske, 2006; Erisman & Roemer, 2010; Kiken & Shook, 2011), pre-post designs

(Evans et al., 2008; Evans, Ferrando, Carr, & Haglin, 2011), correlational studies (Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010) and controlled research of mindfulness programmes (Goldin & Gross, 2010; Jain et al., 2007; Kabat-Zinn et al., 1992; Kaviani, Javaheri, & Hatami, 2011; Koszycki, Benger, Shlik, & Bradwejn, 2007; Orzech, Shapiro, Brown, & McKay, 2009; Piet, Hougaard, Hecksher, & Rosenberg, 2010; Ramel, Goldin, Carmono, & McQuaid, 2004; Speca, Carlson, Goodey, & Angen, 2000; Vøllestad et al., 2011; Warnecke, Quinn, Ogden, Towle, & Nelson, 2011). Preliminary evidence further suggests that mindfulness combined with psychotherapy or pharmacotherapy can be more effective than either treatment alone (Barnhofer et al., 2009; Bondolfi et al., 2010; Goldfrin & van Heeringen, 2010; Hepburn et al., 2009; Kim et al., 2009).

Neuroscientific data demonstrates similarities within the neurobiology of anxiety disorders and mindfulness. Neurocognitive models of anxiety (Bishop, 2007, 2008; Davidson, 2002; Davis & Whalen, 2001) and conceptual accounts, such as attentional control theory (Derakshan & Eysenck, 2009; Eysenck, Derakshan, Santos, & Calvo, 2007), have highlighted that the development and maintenance of anxiety represents dysfunction within amygdala-prefrontal pathways, manifested in debilitated top-down attentional control and enhanced bottom-up processing. These theorisations have been supported by neurobiological evidence (Anderson & Phelps, 2001; Bishop, Duncan, Brett, & Lawrence, 2004; Browning, Holmes, Murphy, Goodwin, & Harmer, 2010; Carlson, Reinke, & Habib, 2009; Monk et al., 2004; Nitschke et al., 2009; Stein, Simmons, Feinstein, & Paulus, 2007; van den Heuvel et al., 2005). In contrast, mindfulness has been shown to improve attentional abilities and higher-order control mechanisms, indicated by neuroplastic changes within frontal cortical structures such as the prefrontal cortex and functionally-related components (e.g., anterior cingulate cortex) that down-regulate subcortical regions (Barnhofer, Chittka, Nightingale, Visser, & Crane, 2010; Creswell, Way, Eisenberger, & Lieberman, 2007; Goldin & Gross, 2010; Kilpatrick et al., 2011; Modinos, Ormel, & Aleman, 2010; van den Hurk, Janseen, Giommi, Barendregt, & Gielen, 2010; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). Moreover, preliminary evidence shows direct effects of mindfulness on attentional biases that confer vulnerability to anxiety (Garland, Gaylord, Boettiger, & Howard, 2010; Ortner, Kilner, & Zelazo, 2007; Vago & Nakamura, 2011).

Whilst it is likely that mindfulness does not exert its benefits solely through relaxation (e.g., Rubia, 2009), mindfulness is associated with physiological indicators of stress reduction, such as reduced systolic and diastolic blood pressure (BP) (Campbell, Labelle, Bacon, Faris, & Carlson, 2012; Carlson, Speca, Patel, & Faris, 2007; Palta et al., 2012), improved heart rate (Zeidan, Johnson, Gordon, & Goolkasian, 2010), decreased cortisol levels (Carlson et al., 2007; Jensen, Vangkilde, Frokjaer, & Hasselbalch, 2011) and improved immune function (Carlson et al., 2007; Davidson et al., 2003). Long-term meditation that is conceptually and phenomenologically similar to mindfulness has also been associated with physiological changes suggestive of a wakeful hypometabolic state of enhanced parasympathetic dominance associated with relaxation and attenuated sympathetic activity involved in fight/flight mechanisms of anxiety (Cahn & Polich, 2006; Young & Taylor, 2001). Moreover, there is some evidence of the modulation of neurochemicals that regulate affect, such as dopamine, melatonin and serotonin following meditative practice (see Rubia, 2009 for a review).

A growing body of evidence demonstrates the positive effects of mindfulness on anxiety, affect and negativity bias following brief inductions of 10 minutes

(Erisman & Roemer, 2010), 15 minutes (Arch & Craske, 2006; Barnhofer et al., 2010; Kiken & Shook, 2011), 60 minutes (Zeidan, Johnson, Gordon, et al., 2010) and short interventions of four sessions (Jain et al., 2007; Zeidan, Johnson, Diamond, et al., 2010). Similarly, meta-analyses of programmes of 4-12 sessions have found that effect size is not moderated by number of treatment sessions (Carmody & Baer, 2009; Hofmann et al., 2010). These findings further highlight the potential role of brief mindfulness applications for individuals who may be unable or unwilling to participate in longer interventions such as MBSR or MBCT that typically comprise of a duration of 8-10 weeks.

However, common methodological constraints have prevented firm conclusions regarding the efficacy and effectiveness of mindfulness (Krisanaprakornkit et al., 2009). Limitations have included non-randomisation, the absence of single or double-blind designs, differential attrition rates across conditions and small sample sizes. The evidence-base is also heavily influenced by uncontrolled studies and research that has employed control conditions that are structurally different, such as pharmacological interventions or unspecified mental health approaches. Furthermore, mindfulness has typically been evaluated as one component of wider interventions such as MBSR and MBCT that encompass additional components, such as relaxation and cognitive restructuring. Despite this, the finding that mindfulness is associated with salutary effects is robust and therefore requires further empirical validation. Further research is also warranted to examine minimal and optimal doses of mindfulness.

1.4 Differential Effects of Distinct Meditation Styles

Less is known about the differential efficacy of mindfulness and meditation variants. No studies to date have compared variations of mindfulness practice within a single design and very few have directly compared variations between meditation practices, with contrasting results. A recent study of 55 experienced practitioners with prior experience (average 12.2 years) of Transcendental meditation (mantra meditation) or Zen/Vipassanā meditation (a combination of narrow and open focused mindfulness meditation) did not differ in self-reported dispositional mindfulness or psychological wellbeing (Schoormans & Nyklíček, 2011). Similarly, a study of 14 participants experiencing clinically significant symptoms of obsessive compulsive disorder (OCD) found non-significant differences between the effects of Kundalini yoga adapted to address symptoms of OCD and a relaxation/mindfulness meditation group (as measured by the Yale-Brown Obsessive-Compulsive Scale; Goodman et al., 1989). However, less stress and increased purpose in life was observed following Kundalini yoga at 3 months post-test (Shannahoff-Khalsa et al., 1999). A study that compared 15-minute inductions of a mindfulness breathing practice or Loving-Kindness/mettā meditation (meditation that emphasises loving-kindness towards the self) in 15 meditation-naïve and previously clinically depressed participants found that, whilst both inductions were associated with stronger relative prefrontal activation thought to represent tendencies to approach rather than avoid, the relationship was moderated by self-reported levels of rumination (Barnhofer et al., 2010). As demonstrated by a significant three-way (time x meditation/mindfulness group x rumination) interaction, participants with higher and lower self-reported rumination responded more positively to the mindfulness breathing and Loving-Kindness meditation, respectively. Wachhlotz and Pargament (2005) also found differential effects of spiritual and secular meditative styles; meditation-naïve participants who practiced a spiritual meditation for 20 minutes/day for 2 weeks showed significantly decreased anxiety and improved mood compared to a secular form of mantra meditation and a relaxation control.

These studies reflect that subtle and significant differences in focus, process and subject/object relation between different styles may be associated with diverse neural, cognitive, behavioural and affective correlates (Chiesa & Malinowski, 2011; Dorjee, 2010; Travis & Shear, 2010). However, these forms of meditation are likely to be qualitatively different from the mindfulness techniques and strategies offered within contemporary mental health practices. Moreover, limited research consensus regarding conceptualisations of mindfulness as either a dispositional trait, transient mental state or process (Davidson, 2010) and as a construct comprising of either single (e.g., Brown & Ryan, 2003) or multiple facets (e.g., Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006), has made comparisons across studies difficult.

Within the meditation literature, distinctions have been made between focused attention and open monitoring in recognition of the significant difference that exists between practices and in attempts to deconstruct subcomponents of meditation. Focused attention describes attention that is directed to the breath or another chosen object, whilst open monitoring is characterised by the moment-to-moment monitoring of cognitive and emotional patterns (e.g., Lutz, Slagter et al., 2008). Whilst some propose that focused attention and open monitoring are exclusive entities (e.g., Dunn, Hartigan, & Mikulas, 1999), others suggest that open monitoring represents a progression of focused attention (Lutz, Brefczynski-Lewis, Johnstone & Davidson, 2008; Lutz, Dunne, & Davidson, 2008). Whereas some studies that have directly compared practices based on these distinctions within the field of attention (Jha, Krompinger, & Baime, 2007; Manna et al., 2010) and pain experience (Grant & Rainville, 2009; Perlman, Salomons, Davidson, & Lutz, 2010) have highlighted differential effects of narrow-focused and open-focused meditation styles, others have found non-significant differences (Chan & Woollacott, 2007). Although there are differences between mindfulness and meditation in their conceptualisation and practice, focused mindfulness (FM) is comparable to focused attention meditation in its focus on one chosen object and open mindfulness (OMi) is similar to open monitoring in its cultivation of a wider, receptive awareness. Therefore, further research is warranted to compare the differential effects of FM and OMi across multiple subjective, autonomic and psychological measures of cognition and emotion.

1.5 The Carbon Dioxide (CO_2) Challenge

Inhalation of 7.5% CO_2 has been increasingly utilised within the research literature to provide a putative experimental model of generalised anxiety disorder (GAD[4]; Bailey et al., 2011; Bailey, Papadopoulos, Seddon, & Nutt, 2009; Papadopoulos, Rich, Nutt & Bailey, 2010). The model quantitatively and qualitatively differs from the established vital capacity inhalation of 35% CO_2 model of panic (Rassovsky & Kushner, 2003; see Vickers, Jafarpour, Mofidi, Rafat, & Woznica, 2012 for a detailed review of the 35% CO_2 model of panic). Inhalation of 7.5% CO_2 has been associated with heightened self-report levels of anxiety and worry, increased BP, heart rate and respiratory rate (Bailey, Argyropoulos, Kendrick, & Nutt, 2005; Bailey et al., 2009) and cognitive dysfunction representative of GAD, such as facilitated attention to and delayed disengagement from aversive stimuli (Garner, Attwood, Baldwin, James, & Munafò, 2011). Findings that acute Benzodiazepine administration and the chronic use of selective serotonin reuptake

[4] Generalised anxiety disorder is characterised by excessive, uncontrollable worry that is prolonged over a period of time and disproportionate to the actual source of worry (American Psychiatric Association, 2000; World Health Organization, 1992). Associated physiological symptoms of anxiety, such as breathlessness, perspiration, muscle tension, increased heart rate and elevated BP are also present. Primary psychological characteristics include difficulty concentrating, irritability and agitation. Clinically significant levels of anxiety reflect these symptoms to a magnitude that impair functioning in everyday life and cause significant distress over a prolonged period of time.

inhibitors effective in the treatment of GAD also moderates subjective responses to the 7.5% inhalation in healthy volunteers provides further validation for this model (Bailey, Kendrick, Diaper, Potokar, & Nutt, 2007). However, given that few studies have examined the effects of brief mindfulness inductions within clinical samples, the CO_2 healthy human model of GAD provides a useful experimental proxy with which to compare the efficacy of FM and OMi across subjective and autonomic outcomes.

1.6 The Present Study

This study represents a randomised control trial (RCT) of the effects of 10-minute inductions of FM, OMi and relaxation (control group) on (i) self-reported state anxiety and affect and (ii) autonomic measures of arousal within healthy, meditation-naïve volunteers in the 7.5% CO_2 model of anxiety. A primary aim of this research is to examine the prophylactic effects of FM and OMi compared to relaxation controls. A secondary aim of this study is to reveal any differential effects of FM and OMi on CO_2-induced anxiety and autonomic arousal. The experimental hypotheses are as follows:

1. Participants across all groups will experience heightened levels of anxiety and negative affect following 7.5% CO_2 inhalation, as measured by self-report measures and autonomic measures of arousal, compared to the inhalation of air.
2. Participation in both FM and OMi will be associated with significantly reduced state anxiety and negative affect, as measured by self-report measures and autonomic measures of arousal, compared to the relaxation group.

2.0 Method

2.1 Design

This research employed a quantitative mixed design with the between-subjects independent variable of condition (FM vs. OMi vs. relaxation [control]), and inhalation (7.5% CO_2 vs. usual medical air) as the within-subjects variable. The dependent variables were state anxiety and associated mood, as measured by self-report questionnaires and measures of autonomic arousal. Participants also completed additional computerised tasks as this research was a component of a wider study (to be reported elsewhere by different authors - please refer to the flow chart in appendix A outlining all of the tasks completed by participants).

2.2 Participants

Opportunity sampling using poster advertisements and through the School of Psychology's online study recruitment website 'Psychobook' was used to recruit healthy undergraduate volunteers from the University of Southampton. Participants were offered either student credit or monetary compensation for their involvement (£6/hour). Participants engaged within a pre-test neuropsychiatric screening interview based on the Mini International Neuropsychiatric Interview (Sheehan et al., 1998). This schedule is based on criteria of the Diagnostic and Statistical Manual of Mental Disorder, 4th Edition (DSM-IV; American Psychiatric Association [APA], 1994). Exclusion criteria included (i) current/lifetime history of personal or familial psychiatric illness (including panic attacks), cardiovascular or respiratory disease (including asthma), (ii) current/historical migraines requiring treatment, (iii) current, past and/or recent drug or alcohol dependency, (iv) consumption of ≤ 8 caffeinated drinks daily and ≤ 50 alcoholic units/week (males) and ≤ 35 alcoholic units/week (female), (v) medication use (with the exception of local treatment, oral or injectable contraception, stable [≥ 3 months] HRT and occasional aspirin or paracetamol use) during the preceding 8 weeks, (vi) pregnancy or breastfeeding, (vii) smokers, (viii) under- or overweight (body mass index ≤ 18 or ≥ 28 kg/m^2), (ix) high BP (>140/90 mm Hg) and (x) prior experience of mindfulness or meditation.

Of 104 individuals that volunteered for participation in the study, data from 44 participants was excluded from the final sample; 33 participants met the exclusion criteria and 11 participants chose to withdraw during the study[5]. Thus, data was obtained from 60 participants. The age of the final sample was between 18 and 31 years (m = 20.73 years; SD = 2.74 years). The FM group consisted of 26 participants (18 female, 8 male), aged between 18 and 27 years (m = 20.15 years; SD = 2.26 years) and the OMi group consisted of 23 participants (16 female, 7 male), aged between 18 and 31 years (m = 20.39 years; SD = 2.33 years). The control group consisted of 11 participants (6 female, 5 male), aged between 20 and 31 years (m = 22.82 years; SD = 3.71 years). There were no significant differences between these groups in terms of age ($F(2,57) = 2.75$, $p = .07$) or gender ($\chi^2(2) = .89$, $p = .64$).

Demographic characteristics of the final sample are shown in Table 1. As measured at baseline, participants' levels of trait anxiety (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983: m = 34.80, SD = 7.20) and worry (Gillis, Haaga, & Ford, 1995: m = 42.20, SD = 11.50) were indicative of those reported in healthy control samples[6]. Fear of anxiety sensations was also comparable to healthy controls (Owens, Hadjistavropoulos, & Asmundson, 2000: m = 16.42, SD = 8.00 and m = 17.63, SD = 10.33 for males and females < 60 years, respectively). This sample was

[5] Power calculations using G*Power version 3 (Faul, Erdfelder, Lang, & Buchner, 2007) determined that a total sample size of 101 participants would be required to achieve effect sizes at least as great as those of Bohlmeijer et al. (2010), Hofmann et al. (2010), Ledesma and Kumano (2009), and Vøllestad et al. (2011) ($d \geq .47$), with 87% power and 5% significance level. However, previous research (e.g., Garner et al., 2011) demonstrates strong subjective and autonomic effects of the CO_2 challenge within a total sample of 26, whilst other researchers have revealed strong effects of mindfulness on subjective anxiety and affect in total groups of 60-68 (e.g., Arch & Craske, 2006; Vøllestad et al., 2011; Zeidan, Johnson, Diamond et al., 2010).

[6] Comparable findings, as indicated by ≤ 2 standard deviations.

representative of non-clinical, meditation-naïve populations in terms of dispositional mindfulness, as measured by the Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006) (Baer et al., 2008: FFMQ-Observe subscale: *m* = 24.32, *SD* = 5.84, FFMQ-Describe subscale: *m* = 24.63, *SD* = 7.06, FFMQ-Act With Awareness subscale: *m* = 24.57, *SD* = 6.57, FFMQ-Non-Judging subscale: *m* = 23.85, *SD* = 7.33, FFMQ-Non-React subscale: *m* = 19.53, *SD* = 4.88). Participants' ability to regulate their attention was also comparable to that obtained in other student samples (Verwoerd, de Jong, & Wessel, 2008: *m* = 53.06, *SD* = 5.18). Moreover, pre-test levels of state anxiety (Kennedy, Schwab, Morris, & Beldia, 2001: *m* = 36.00, *SD* = 12.00), positive affect (Crawford & Henry, 2004: *m* = 31.31, *SD* = 7.65) and negative affect (Crawford & Henry, 2004: *m* = 16.00, *SD* = 5.90) were similar to non-clinical samples.

2.3 Measures

Participants completed the following questionnaire measures to determine if groups were matched in anxiety, affect, dispositional mindfulness and attentional control.

2.3.1 Spielberger State-Trait Anxiety Inventory – Form Y (STAI; Spielberger et al., 1983). Trait anxiety has been described as long-standing anxiety associated with personality factors and state anxiety has been characterised by its temporary and emotional nature (Spielberger et al., 1983). This theoretical distinction has been empirically validated (Oei, Evans, & Crook, 1990). The STAI consists of two 20-item subscales assessing state (STAI-S) and trait (STAI-T) anxiety on a 4-point scale. Scores range from 20-80, with higher scores reflecting higher levels of anxiety. Both subscales have good internal consistency (α = .93 and .90, respectively), test-retest reliability (*r* = .16-.62 and *r* = .73-.86, respectively) and convergent and discriminant validity (Spielberger et al., 1983).

2.3.2 Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990). The 16-item PSWQ uses a 5-point rating scale to assess the excessiveness, uncontrollability and severity of worry. Possible scores range from 16-80, with lower scores indicative of lower levels of worry. The PSWQ has good validity, internal consistency (α = .86-.93; Hazlett-Stevens, 2008), test-retest reliability (*r* = .74-.93; Molina & Borkovec, 1994) and can be used to screen for the presence of GAD (Harrington & Antony, 2009).

2.3.3 Anxiety Sensitivity Index (ASI; Peterson & Reiss, 1993). This 16-item scale measures fear and anxiety-related symptoms on a 5-point scale. The measure has good internal consistency (α = .82-.91) and satisfactory test-retest reliability (*r* = .71-.75), criterion validity and construct validity (Peterson & Reiss, 1993). The possible range of scores is 0-64, with higher scores reflecting increased anxiety sensitivity.

2.3.4 Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). The PANAS is a 20-item self-report measure of positive and negative affect. The measure utilises a 5-point rating scale and possible scores range from 10-50. Higher scores on the PANAS-P reflect increased positive affect, which has been conceptualised as the extent to which participants feel active, happy and energised. Lower scores on the PANAS-N represent lower levels of negative affect and participants' levels of general distress, as indicated by feelings such as anger, fear, nervousness and guilt. The subscales of positive affect (PANAS-P) and negative affect (PANAS-N) have good internal consistency (α = .89 and .85, respectively), convergent validity (Crawford & Henry, 2004) and test-retest reliability (*r* = .68 and .71, respectively; Watson et al., 1988).

2.3.5 Mindfulness Attention Awareness Scale (Brown & Ryan, 2003). The MAAS is a 15-item single-factor measure of one's general awareness and attentiveness to the present-moment, with good internal consistency (α = .82-.87), test-retest reliability (*r* = .81) and convergent validity (Brown & Ryan, 2003). The MAAS uses a 6-point rating scale, with higher scores reflecting higher levels of dispositional mindfulness.

2.3.6 FFMQ (Baer et al., 2006). The FFMQ is a 39-item measure rated on a 5-point Likert scale. The measure consists of five subscales that assess dispositional mindfulness in daily life: (i) observing (noticing or attending to internal or external experiences), (ii) describing (labelling experiences with words), (iii) acting with awareness (attending to the activity in which one is currently engaged), (iv) non-judging of inner experience (a non-evaluative stance towards cognitions and emotions) and (v) non-reactivity to inner experience (observing thoughts and feelings without reacting to them). Possible scores range from 8-40 for all subscales, with the exception of the non-reactivity to inner experience subscale that ranges from 7-35. Higher scores reflect higher levels of dispositional mindfulness on all subscales. The FFMQ has demonstrated good internal consistency among non-meditators (α = .75-.91 across subscales) and has been validated in student, community and meditator samples (Baer et al., 2006, 2008). No information is currently available for the test-retest reliability of the English version of the FFMQ but good test-retest reliability has been found for French (Heeren, Douilliez, Peschard, Debrauwere, & Philippot, 2011), Dutch (e.g., Veehof, ten Klooster, Taal, Westerhof, & Bohlmeijer, 2011) and Chinese (Deng, Liu, Rodriguez, & Xia, 2011) translations.

2.3.7 Attention Control Scale (ACS; Derryberry & Reed, 2002). The ACS is a 20-item measure of an individual's ability to regulate their attention. Items are rated on a 4-point rating scale and the possible range of scores is 20-80, with higher scores reflecting enhanced attentional control. The ACS comprises of subscales related to the ability to focus attention (focus subscale), shift attention between tasks (shift subscale) and flexibly control thought (cognitive flexibility subscale). Derryberry and Reed (2002) report some evidence for good convergent validity of the ACS with a behavioural measure of attentional control and good internal consistency between all items (α = .88).

2.3.8 Physiological measures of autonomic arousal. Autonomic arousal was assessed through measurements of systolic BP, diastolic BP and heart rate via a non-invasive procedure using electrodes and a Biopac MP 150 amp (Omron-M6, Medisave, UK).

2.4 Procedure

An initial telephone-administered neuropsychiatric screening (appendix B) was supplemented with follow-up screening on the day of testing (appendix C), following verbal and written informed consent. Individuals attended a single test session in which they completed baseline self-report measures of (i) trait anxiety (STAI-T), worry (PSWQ) and anxiety sensitivity (ASI), (ii) dispositional mindfulness (FFMQ and MAAS) and (iii) attention control (ACS). Individuals were then randomised to intervention group (FM, OMi or control) and matched on demographic characteristics of age and gender. Measures of self-reported state anxiety (STAI-S), mood (PANAS) and autonomic arousal (systolic BP, diastolic BP and heart rate) were collected across all groups at pre-test prior to the intervention and inhalation. Participants within the experimental conditions engaged in either a 10-minute guided

FM or OMi practice whilst control participants were asked to relax for the same duration (please see section 2.5 for further details). Individuals subsequently inhaled either 7.5% CO_2-enriched medical air or usual medical air delivered through an oro-nasal face mask for 20 minutes. The administration order was counterbalanced across participants blind to the inhalation order. The same measures that were administered at pre-test were completed immediately following inhalation to serve as post-test outcome measures. Following a 25-minute rest period that enabled residual effects of CO_2 inhalation to dissipate where appropriate, the protocol was repeated with inhalation counterbalanced according to prior inhalation. A verbal and written de-brief was provided to all participants following their withdrawal or completion in the study. All participants were contacted by the research team within 24 hours of their participation to confirm their safety and well-being.

2.5 Interventions

FM and OMi were delivered by a 10-minute audio-recording of a Consultant Psychiatrist of the National Health Service (NHS), who had personal experience of mindfulness (20 years) and experience of teaching both forms of mindfulness to clinical and non-clinical groups (12 years). Both interventions were introduced as a series of exercises involving the regulation of attention.

2.5.1 Focused mindfulness (FM). The FM induction involved directing attention to the physical sensation of breathing[7]. Participants were encouraged to notice and focus their awareness on clear sensations of breathing, for example sensation changes at the tip of the nose, nostril or throat during the in-breath and out-breath. Participants were guided to notice if their attention wandered, disengage from

[7] The MP3 recording for the FM intervention can be accessed at the following URL: goo.gl/tFzpI

the distractor (e.g., a thought) in a non-evaluative and non-judgemental manner and gently return it to rest on the selected sensation.

2.5.2 Open mindfulness (OMi). The OMi induction began with the direction of participants' attention to the physical sensation of breathing. Participants were instructed to focus their attention on the in-breath and out-breath at points in the body where these sensations were most clear, such as the tip of the nose, inside the nostrils, back of the throat, chest or abdomen[8]. Participants were guided to practice this narrow form of mindfulness for 3.56 minutes (35%) before expanding their field of awareness by progressively noticing other physical sensations and auditory, visual and olfactory stimuli. Participants were subsequently guided to become naturally aware of their emotional tone and cognitive experiences. Participants were encouraged to notice if their attention wandered, disengage from the distractor in a non-evaluative and non-judgemental manner and gently return it to notice moment-by-moment changes in their field of awareness.

2.5.3 Control. The control group comprised of a 10-minute period of unguided relaxation. Participants were in the same environment as the experimental conditions but were given only instructions to relax.

2.6 Ethical Considerations

Ethical approval was granted from the School of Psychology Ethics Committee and the Research Governance office, University of Southampton (appendix D). All participants provided informed consent (appendix E) and were formally debriefed (appendices F and G). No participants reported adverse effects associated with their engagement in this study at 24 hours following their participation.

[8] The MP3 recording for the OMi intervention can be accessed at the following URL: goo.gl/rH8R9

3.0 Results

3.1 Baseline Characteristics

Histograms indicated that data did not differ substantially from normality, as confirmed by non-significant Kolmogorov-Smirnov tests ($p > .05$). Descriptive and inferential statistics were calculated to examine baseline demographic differences and variations within self-reported trait anxiety/worry, dispositional mindfulness and attentional control between each group (FM, OMi and control), as illustrated within Table 1.

Table 1

Baseline Group Characteristics

	FM		OMi		Control		ANOVA		
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*df*	*p*
Demographic data									
Age	20.69	3.12	20.35	2.35	22.82	3.71	2.75	2,57	.07
Body Mass Index	21.70	2.04	22.44	2.12	22.87	2.51	1.38	2,57	.26
Trait anxiety/worry									
STAI-T	32.28	6.39	32.68	6.59	33.45	4.74	0.14	2,55	.87
ASI	29.15	5.90	31.96	8.70	28.45	4.20	1.39	2,57	.26
PSWQ	42.57	10.29	38.52	11.78	41.00	12.11	0.75	2,54	.48
Dispositional mindfulness									
MAAS	4.10	0.60	3.78	0.59	3.80	0.48	0.84	2,55	.44
FFMQ-Total	129.33	16.36	128.83	11.95	129.18	15.66	0.01	2,55	.99
FFMQ-O	22.44	5.50	21.96	4.88	22.18	4.17	0.06	2,56	.95
FFMQ-D	27.96	5.93	28.00	5.74	28.09	8.51	0.00	2,56	1.00
FFMQ-A	25.52	5.30	26.00	5.54	26.73	6.65	0.18	2,56	.84
FFMQ-NJ	31.76	7.87	31.17	4.76	30.09	8.87	0.22	2,56	.81
FFMQ-NR	21.67	4.52	21.70	4.30	22.09	4.25	0.04	2,55	.96
Attentional control									
ACS-Total	47.46	7.15	49.91	7.79	48.55	8.52	0.59	2,54	.56
ACS-F	18.92	4.68	20.30	4.26	21.45	4.03	1.40	2,56	.26
ACS-S	28.58	4.51	29.32	4.90	27.09	5.47	0.77	2,54	.47
ACS-C	16.96	2.37	17.26	2.61	16.09	3.02	0.76	2,56	.47

Note. STAI-T = State-Trait Anxiety Inventory-Trait subscale; ASI = Anxiety Sensitivity Index; PSWQ = Penn State Worry Questionnaire; MAAS = The Mindfulness Attention Awareness Scale; FFMQ-Total = Five Facet Mindfulness Questionnaire-Total score; FFMQ-O = Five Facet Mindfulness Questionnaire-Observe subscale; FFMQ-D = Five Facet Mindfulness Questionnaire-Describe subscale; FFMQ-A = Five Facet Mindfulness Questionnaire-Act With Awareness subscale; FFMQ-NJ = Five Facet Mindfulness Questionnaire-Non-Judging subscale; FFMQ-NR = Five Facet Mindfulness Questionnaire-Non-React subscale; ACS-Total = Attentional Control Scale-Total score; ACS-F = Attentional Control Scale-Focus subscale; ACS-S = Attentional Control Scale-Shift subscale; ACS-C = Attentional Control Scale-Cognitive Flexibility subscale.

As confirmed by a series of one-way analyses of variance (ANOVAs), participants within each group did not significantly differ from one another at baseline (see Table 1). Participants were demographically similar and did not differ in age (p = .07) or body mass index (p = .26). Participants also reported comparable levels of (i) trait anxiety, as measured by the STAI-T (p = .87) and the ASI (p = .26), and (ii) worry, as measured by the PSWQ (p = .48). Levels of self-reported dispositional mindfulness were also similar across groups, as measured by the MAAS (p = .44) and the FFMQ (p = .81-1.00 across subscales). Additionally, no significant differences were found between participants' capacity to regulate their attention, as indicated by the ACS (p = .26-.56 across scales).

3.2 Pre-Test State Anxiety and Autonomic Arousal

Further analyses were conducted to determine whether participants within each group experienced differing levels of state anxiety, affect and autonomic arousal at pre-test. Table 2 summarises descriptive and inferential statistics calculated using data from measures of anxiety, mood and autonomic arousal, including systolic BP, diastolic BP and heart rate.

Table 2

Group Characteristics at Pre-Test

	FM		OMi		Control		ANOVA		
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*df*	*p*
Self-reported state anxiety									
STAI-S	32.56	7.67	32.50	6.43	34.64	7.31	0.39	2,55	.68
Self-reported state mood									
PANAS-P	26.96	5.71	30.39	5.46	26.50	6.72	2.67	2,56	.08
PANAS-N	11.96	3.77	12.74	3.73	11.90	2.18	0.35	2,56	.70
Autonomic measures of arousal									
SBP	117.54	11.36	117.22	16.69	118.18	9.20	0.02	2,57	.98
DBP	67.38	8.58	72.70	14.86	70.55	10.67	1.27	2,57	.29
HR	71.38	7.77	75.39	10.75	76.18	8.48	1.63	2,57	.21

Note. STAI-S = State-Trait Anxiety Inventory-State subscale; PANAS-P = Positive and Negative Affect Schedule-Positive subscale; PANAS-N = Positive and Negative Affect Schedule-Negative subscale; SBP = Systolic blood pressure; DBP = Diastolic blood pressure; HR = Heart rate.

As confirmed by one-way ANOVAs, participants within experimental and control groups did not significantly differ at pre-test. Participants demonstrated comparable levels of state anxiety, as measured by the STAI-S (p = .68). Similarly, participants reported comparable levels of positive and negative affect, as indicated by the PANAS-P (p = .08) and the PANAS-N (p = .70), respectively. Measures of systolic BP, diastolic BP and heart rate indicated that participants across groups did not experience significantly different levels of arousal at pre-test (p = .21-.98 across measures).

3.3 Acute Effects of Mindfulness on Subjective Levels of Anxiety

To examine the acute effects of mindfulness on subjective levels of state anxiety, as indicated by the STAI-S, groups were compared following a 20-minute inhalation of CO_2 and air. Figure 1 illustrates mean scores obtained on the STAI-S across groups following each inhalation.

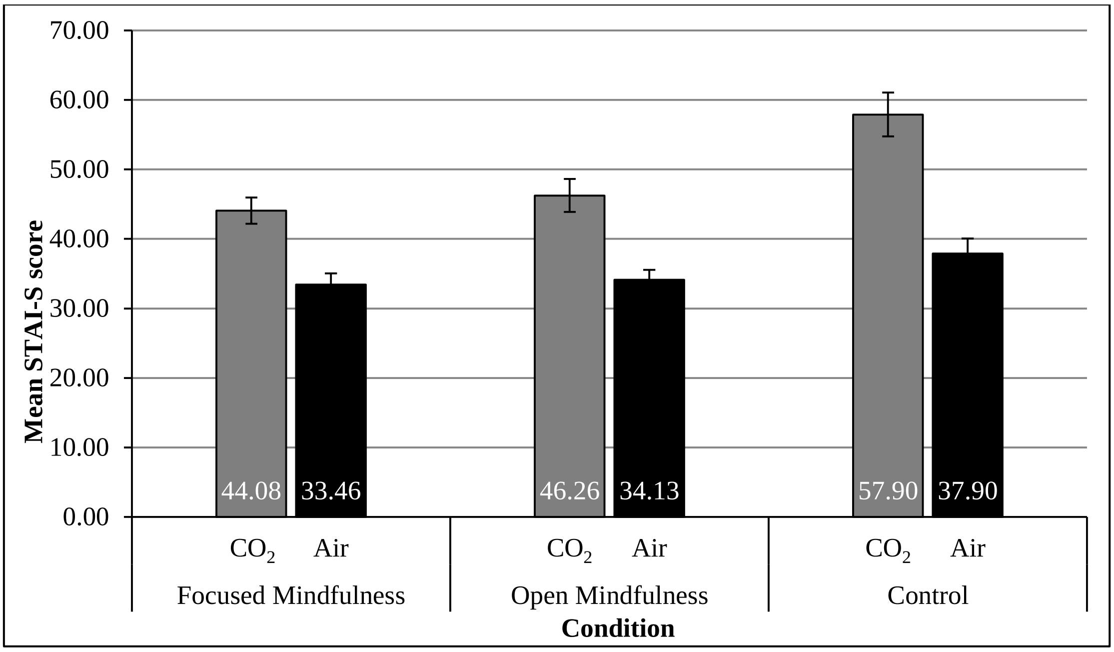

Figure 1. Mean scores on the STAI-S following inhalation of CO_2 and air across each group. Standard errors are represented in the figure by the error bars attached to each column.

A 2 (inhalation) x 3 (group) mixed-design ANOVA demonstrated a significant main effect of inhalation ($F(1,54) = 113.73$, $p < .01$, $d = 1.34$) [9] and a significant interaction between inhalation and group ($F(2,54) = 3.70$, $p < .05$). All groups experienced significantly greater anxiety following CO_2 inhalation, in comparison to air: FM ($t(23) = 5.78$, $p < .05$, $d = 1.22$), OMi ($t(22) = 6.22$, $p < .05$, $d = 1.33$) and relaxation control ($t(9) = 6.33$, $p < .05$, $d = 2.27$). A one-way ANOVA confirmed that the experimental and control groups did not significantly differ following air inhalation ($F(2,56) = 1.06$, $p = .35$). However, as predicted, groups did differ following CO_2 inhalation ($F(2,55) = 7.25$, $p < .05$). Post-hoc tests indicated that both

[9] Cohen's *d* (1992) effect sizes were calculated by dividing mean differences by their pooled standard deviation. Please refer to appendix H for the statistical equations utilised.

FM ($p < .05$, $d = 1.42$) and OMi ($p < .05$, $d = 1.07$) groups experienced significantly reduced anxiety following the CO_2 challenge compared to control participants. There were non-significant differences between the effects of FM and OMi ($p = 1.00$) following CO_2 inhalation.

3.4 Acute Effects of Mindfulness on Subjective Measures of Mood

Similar analyses were completed to examine the acute effects of mindfulness on subjective measures of mood. Group scores on PANAS-N and PANAS-P were compared following CO_2 and air inhalation to determine whether mindfulness effectively reduced negative affect and improved positive affect. Figures 2 and 3 illustrate the mean scores obtained on the PANAS-N and PANAS-P across groups following each inhalation, respectively.

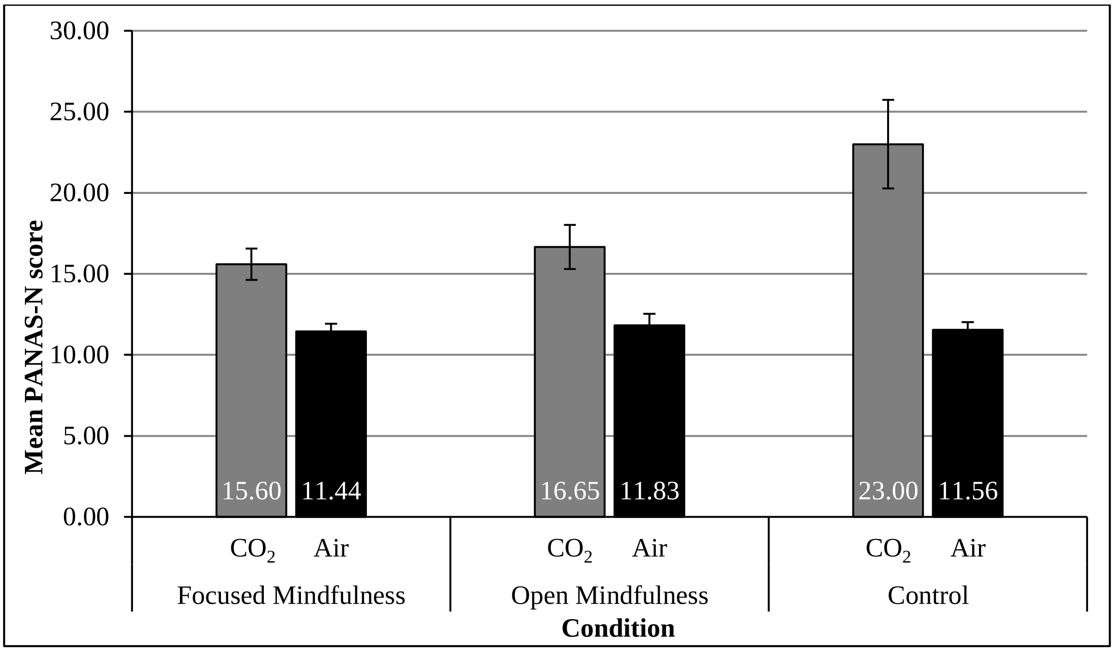

Figure 2. Mean scores on the PANAS-N following inhalation of CO_2 and air across each group. Standard errors are represented in the figure by the error bars attached to each column.

A 2 (inhalation) x 3 (group) mixed ANOVA that examined the effect of mindfulness and inhalation on negative affect demonstrated both a significant main effect of inhalation ($F(1,54) = 67.47$, $p = < .01$, $d = 1.07$) and a significant interaction between inhalation and group ($F(2,54) = 5.87$, $p < .05$). Further comparisons demonstrated significantly elevated levels of negative affect post CO_2 inhalation, in comparison to air inhalation in each group: FM ($t(24) = 4.42$, $p < .05$, $d = 1.10$), OMi ($t(22) = 5.09$, $p < .05$, $d = .95$) and relaxation ($t(8) = 3.59$, $p < .05$, $d = 1.71$). A one-way ANOVA confirmed that the experimental and control groups did not significantly differ at post-test following air inhalation ($F(2,55) = .06$, $p = .94$). However a similar analysis did reveal that groups significantly differed in negative affect post CO_2 inhalation ($F(2,56) = 6.37$, $p < .05$). Consistent with predictions, both FM ($p < .05$, $d = 1.17$) and OMi ($p < .05$, $d = .86$) groups experienced reduced negative affect following CO_2 inhalation compared to the relaxation control group, with no difference between FM and OMi groups ($p = 1.00$).

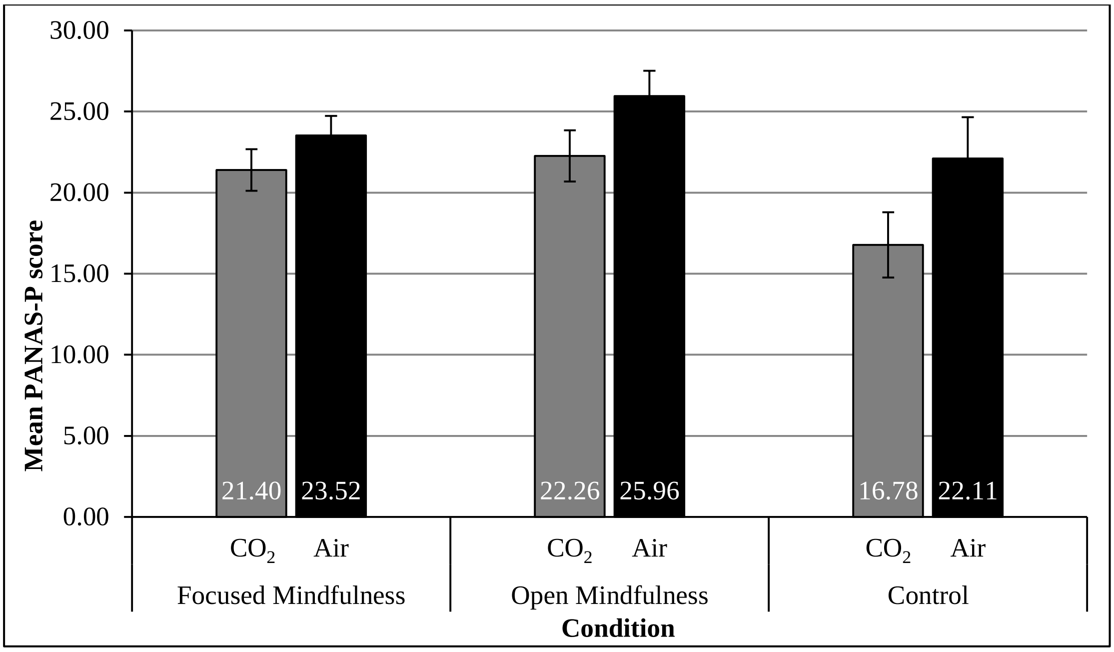

Figure 3. Mean scores on the PANAS-P following inhalation of CO_2 and air across each group. Standard errors are represented in the figure by the error bars attached to each column.

An additional 2 (inhalation) x 3 (group) mixed ANOVA examined the effects of mindfulness and inhalation on positive affect, as measured by the PANAS-P, and found a significant main effect of inhalation ($F(1,54) = 23.28$, $p = < .01$, $d = .46$) but a non-significant interaction between inhalation and group ($p = .26$). These findings suggest that whilst CO_2 inhalation was associated with reduced positive affect, the effect of inhalation on positive affect did not differ across experimental and control groups.

3.5 Acute Effects of Mindfulness on Autonomic Measures of Arousal

To determine the acute effects of mindfulness on autonomic arousal, groups were compared on measures of systolic BP, diastolic BP and heart rate following inhalation of CO_2 and air. Table 3 illustrates mean scores obtained on these measures across groups and following each inhalation.

Table 3

Mean Systolic BP, Diastolic BP and Heart Rate Following Inhalation of CO_2 and Air Across Each Group

	FM				OMi				Control			
	CO_2		Air		CO_2		Air		CO_2		Air	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
SBP	123.83	15.30	113.71	12.02	123.95	13.71	114.23	8.56	122.33	15.26	115.33	7.86
DBP	72.33	7.66	71.13	8.38	74.91	12.33	73.18	7.01	71.00	10.70	72.44	12.45
HR	87.42	18.18	71.29	9.41	86.13	21.56	73.70	15.19	83.38	10.61	67.63	13.21

Note. SBP = Systolic blood pressure; DBP = Diastolic blood pressure; HR = Heart rate

A series of 2 (inhalation) x 3 (group) mixed ANOVAs demonstrated significant main effects of inhalation on measures of systolic BP ($F(1,52) = 36.71$, $p < .01$, $d = .77$) and heart rate ($F(1,52) = 45.07$, $p < .01$, $d = .92$). As illustrated within Table 3, CO_2 inhalation was associated with heightened autonomic arousal, compared to air inhalation. However, these analyses also found non-significant interactions between inhalation and group on measures of systolic BP ($F(2,52) = .34$, $p = .72$) and heart rate ($F(2,52) = .42$, $p = .66$), suggesting that the effect of inhalation on autonomic arousal was not influenced by mindfulness practice. Analyses of diastolic BP indicated a non-significant main effect of inhalation ($F(1,52) = .16$, $p = .69$) and a non-significant interaction between inhalation and group ($F(2,52) = .46$, $p = .63$), suggesting that diastolic BP was not modulated by CO_2 inhalation nor mindfulness practice.

4.0 Discussion

This study examined the effects of FM and OMi inductions on 7.5% CO_2-induced state anxiety and autonomic arousal. It was hypothesised that participants across all groups would experience heightened subjective and objective increases in anxiety and negative affect following CO_2 inhalation, compared to air inhalation. It was also anticipated that the beneficial effects of mindfulness broadly reported in the research literature would be evident across subjective and autonomic outcomes in the CO_2 model. Therefore, it was hypothesised that participation in both FM and OMi would be associated with significantly reduced self-reported state anxiety, affect and autonomic arousal, compared to a period of relaxation. Although the evidence-base regarding differential effects of distinct meditation styles is sparse and constrained by methodological limitations, there is some preliminary evidence of the differences between disparate meditation practices within direct comparisons (Barnhofer et al., 2010; Grant & Rainville, 2009; Jha et al., 2007; Manna et al., 2010; Perlman et al., 2010; Shannahoff-Khalsa et al., 1999; Wachhlotz & Pargament, 2005). Therefore, a secondary aim of this study was to reveal any differences that may exist between FM and OMi on CO_2-induced anxiety and mood.

4.1 Key Findings

4.1.1 Validity of the CO_2 challenge. As predicted, the results provide further support for the empirical validation of the 7.5% CO_2 challenge. As measured by the STAI-S, participants reported heightened anxiety following CO_2 inhalation, in comparison to air inhalation, across all groups. Compared to air inhalation, CO_2 inhalation was also associated with significantly elevated negative affect and reduced positive affect across all groups, as measured by the PANAS-N and PANAS-P, respectively. The magnitude of these effects is consistent with previous literature (e.g., Garner et al., 2011). Moreover, the mean scores of control participants at post-test are comparable to levels of state anxiety and affect observed within clinically anxious and depressed samples, as measured by the STAI-S (Kennedy et al., 2001: *m* = 52.00; *SD* = 13.00), PANAS-N (Durham et al., 2011; *m* = 32.40, *SD* = 7.70) and PANAS-P (Durham et al., 2011: *m* = 24.20, *SD* = 8.10).

Although increased autonomic arousal following CO_2 inhalation was indicated by elevated systolic BP and heart rate, the results suggest that diastolic BP was not modulated by the CO_2 challenge. Studies have consistently found increases in systolic BP and heart rate following 7.5% CO_2 inhalation (Bailey et al., 2005; Bailey et al., 2011; Cooper et al., 2011; Garner et al., 2011); however, changes in diastolic BP have been less consistent, with some demonstrating increases (e.g., Bailey et al., 2011; Cooper et al., 2011) and others indicating no change (e.g., Bailey et al., 2005; Garner et al., 2011). It is possible that changes in diastolic BP are less consistently found since it is considered to be a less reactive measure of autonomic arousal than systolic BP (Hilmert, Ode, Zielke, & Robinson, 2010; Vickers et al., 2012).

4.1.2 Prophylactic effects of FM and OMi. As predicted, the results suggest that both FM and OMi were associated with significantly reduced self-reported state anxiety, compared to relaxation. The large effect sizes observed in this study should be interpreted with caution since it is likely that these were somewhat inflated by the small sample size (Fern & Monroe, 1996). However, these results are similar to those observed within other brief mindfulness interventions, where reported (η^2 = .46; Zeidan , Johnson, Diamond, et al., 2010) and mindfulness interventions of between 6-15 weeks (*d* = .47-.97; Bohlmeijer, Prenger, Taal, & Cuijpers, 2010; Ledesma & Kumano, 2009; Vøllestad et al., 2011; Hedges' *g* = .63-.97; Hofmann et al., 2010). These findings are also consistent with meta-analytic research that indicates that treatment effects are not moderated by intervention duration (Carmody & Baer, 2009; Hofmann et al., 2010). The evidence-base suggests a positive correlation between intensity and duration of mindfulness practice and the degree to which anxiety is attenuated, however, this study indicates that even brief inductions of 10 minutes can beneficially reduce pharmacologically-induced anxiety.

FM and OMi were also associated with significantly reduced negative affect compared to a period of relaxation, as measured by the PANAS-N. These results are consistent with research that has demonstrated the beneficial effects of brief mindfulness (d = 1.36; Jain et al., 2007; approaching significance η_p^2 = .17; Erisman & Roemer, 2010; η^2=.52; Zeidan, Johnson, Gordon, et al., 2010; r^2= .07; Arch & Craske, 2006) and of longer mindfulness interventions (Hedge's g = .63-1.52; Barnhofer et al., 2009; Kenny & Williams, 2007; Kingston, Dooley, Bates, Lawlor, & Malone, 2007; d = .97; Vøllestad et al., 2011).

This research did not find that mindfulness was associated with improved positive affect significantly more so than a period of relaxation, as measured by the PANAS-P. Most research has utilised only single-factor measures of negative affect and depression, such as variants of the Beck Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961), Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1971), Hamilton Depression Rating Scale (HAM-D; Hamilton, 1960) and the Centre for Epidemiological Studies-Depression Scale (CES-D; Radloff, 1977). In doing so, these studies have not directly examined the effects of mindfulness on positive affect. Studies that have utilised variants of the PANAS-P to examine the effects of mindfulness programmes of 8 weeks have typically found significant increases in positive affect following mindfulness (e.g., Anderson et al., 2007; Shapiro, Brown, & Biegel, 2007). However, studies of brief mindfulness inductions have generally found non-significant differences between experimental and control conditions using the same measure (Arch & Craske, 2006; Kiken & Shook, 2011). Although Erisman and Roemer (2010) found that brief FM was associated with increased positive affect following the viewing of an amusing film clip, mindfulness was not associated with improved affect following the viewing of negative or mixed-affect clips. Consistent with theoretical conceptualisations and empirical evidence that suggests that positive and negative affect are relatively independent and largely uncorrelated constructs (e.g., Watson et al., 1988), it is possible that 10 minutes of mindfulness effectively reduced negative affect but was not extensive enough to influence positive affect under conditions of stress. Moreover, the PANAS-P is reported to measure the extent to which an individual feels "enthusiastic, active and alert" (Watson et al., 1988, p. 1063) and therefore it is probable that more intensive and longer mindfulness practice is required to achieve these effects. These possibilities are consistent with Jha et al.'s (2010) findings of positive correlations between the frequency of mindfulness and enhanced positive affect, as measured by the PANAS-P.

Non-significant differences between the experimental and control groups at post-test indicate that mindfulness practice was not associated with significant reductions in autonomic arousal. Other preliminary trials that have examined physiological changes associated with brief mindfulness inductions have also found no change (Arch & Craske, 2006; Erisman & Roemer, 2010). The finding of reduced self-reported anxiety and negative affect in the context of non-significant changes in autonomic arousal suggest that mindfulness does not exert its effects solely through relaxation or reduced arousal. These findings therefore provide further evidence for the effect of mindfulness on the subjective experience of distress independent of arousal. It is likely that physiological changes are moderated by mindfulness practice of a longer duration than that evaluated within this research. This notion is consistent with findings that extensive meditation is associated with physiological changes that reflect reduced stress (Cahn & Polich, 2006; Young & Taylor, 2001) and preliminary examinations of longer interventions reporting that mindfulness is associated with reduced systolic BP (Campbell et al., 2012; Carlson et al., 2007), diastolic BP (Palta et al., 2012) and heart rate (Zeidan, Johnson, Gordon, et al., 2010). These propositions are in accordance with contemporary conceptualisations and empirical evidence that advocate that the beneficial effects of mindfulness are obtained through specific rather than non-specific effects. These findings are also consistent with proposed frameworks of synergistic interactions between distinct but interrelated mechanisms such as attention, self-focused awareness, emotion regulation, enhanced mind-body functioning, relaxation, acceptance and meta-cognitive shifts (e.g., Baer, 2009; Dorjee, 2010; Hölzel, Lazar, et al., 2011).

4.1.3 Differential effects of FM and OMi. Differential effects of FM and OMi on measures of self-reported state anxiety, affect and autonomic arousal were not found in this study. A lack of distinction between these groups may be attributable to a significant component of FM practice (35%) necessarily encompassed within the OMi intervention to enable participants to acquire fundamental skills that are a prerequisite to the development of a wider field of awareness. This is consistent with suggestions that the acquisition of open mindfulness is contingent on the attainment of narrow-focused mindfulness (e.g., Lutz, Brefczynski-Lewis, et al., 2008; Lutz, Dunne, et al., 2008). It is possible that participants within both groups acquired skills most representative of FM and that further practice is required to enable valid comparisons of the differential effects of FM and OMi. Accordingly, studies that have found differences between variants of meditation have either included long-term practitioners (Grant & Rainville, 2009; Manna et al., 2010; Perlman et al., 2010; Schoormans & Nykliček, 2011), examined longer intervention periods of 3 months (Shannahoff-Khalsa et al., 1999) and/or compared meditation practices that are very diverse, such as Transcendental meditation (Schoormans & Nykliček, 2011), Loving-Kindness/mettā meditation (Barnhofer et al., 2010) or yoga (Shannahoff-Khalsa et al., 1999).

4.2 Clinical Implications

This study demonstrates the efficacy of brief mindfulness practice in reducing pharmacologically-induced anxiety and negative affect. These findings contribute to the developing evidence-base suggesting that brief mindfulness interventions that are viable within the NHS may be effective in the treatment of anxious and affective symptomatology that continue to be highly prevalent and associated with a range of adverse personal, societal and economic outcomes (e.g., Krisanaprakornkit et al., 2009; NICE, 2011; Wittchen & Jacobi, 2005).

Mindfulness-based interventions have been most consistently examined within the context of trans-diagnostic group formats, which provide a cost-effective and time-efficient delivery, in line with national imperatives (Department of Health, 2011; The British Psychological Society, 2009). As highlighted by key priorities for implementation (NICE, 2011), access to mental health treatments for common mental health problems continues to be problematic. It is suggested that mindfulness applications could be effective at every level in a stepped-care approach. Preliminary research suggests that internet-delivered applications of mindfulness can effectively reduce anxiety and improve quality of life (d = .78-1.11; Ljótsson et al., 2011). The present study suggests that the delivery of mindfulness applications using audiomedia could be useful (i) within self-facilitated treatments, (ii) for those individuals unable to access mental health services due to mobility, socio-economic and/or psychological difficulties and (iii) for those who prefer not to engage in individual therapy. Furthermore, it is possible that translated formats may contribute to improved access for some ethnic minority populations that are currently underserved (Department of Health, 2011). Preliminary evidence also suggests that mindfulness can be effective as an adjunct to psychological and pharmacological interventions (Chiesa & Serretti, 2011).

Moreover, the findings highlight that the establishment and empirical validation of interventions in which mindfulness is a key component, such as ACT and DBT, and the development of novel mindfulness approaches will continue to be important. The development, validation and application of mindfulness may alleviate some of the limitations and constraints of current treatment approaches of anxiety. It may also represent exciting opportunities for the future of mental health treatments for a range of varied psychological and physical problems.

4.3 Critique and Future Directions

4.3.1 Sample characteristics. This study usefully supplemented case-controlled studies that have compared experienced meditators to novice practitioners or control participants in its recruitment of meditation-naïve participants and matched controls. This is important since those seeking treatment for anxiety are likely to differ from long-term meditators with regards to personality, health, affective characteristics and expertise. Moreover, this design avoids confounds associated with the inclusion of experienced meditators who may inadvertently use techniques more representative of open monitoring when engaged in focused attention tasks due to their improved attentional abilities and receptive awareness (Lutz, Brefczynski-Lewis, et al., 2008). This sample also explored the prophylactic effects of mindfulness on levels of state anxiety and depression representative of that observed in clinical samples and therefore elaborates on results of designs employing healthy volunteers not under conditions of stress.

However, there are several important methodological limitations that require consideration and indicate that further research is warranted. Most notably, this study is limited by a small sample size and a particularly modest control group, which reduced the statistical power of the analyses. The sample size of this research is similar to other laboratory trials of mindfulness inductions (e.g., Arch & Craske, 2006; Barnhofer et al., 2010; Erisman & Roemer, 2010), thus highlighting the need for further replication with large sample sizes.

Moreover, although RCTs have been described as the ‘gold standard’ to test the efficacy or effectiveness of healthcare services and have been useful to persuade healthcare funding organisations of the efficacy of psychotherapeutic interventions, they often lack ecological validity, thereby limiting the generalisability of findings to clinical practice. The strict exclusion criteria adopted by this study and the resulting homogenous sample is representative of this dilemma. This study usefully avoided potential confounds associated with a diverse sample. However, the ability to generalise the findings to individuals with co-morbid physical and psychological difficulties, varying socio-economic backgrounds, diverse cognitive abilities, trauma-histories, concurrent use of pharmacological or psychological therapy and a range of personality characteristics, representative of those who often present to mental health services (Morrison, Bradley, & Westen, 2003), may be somewhat limited. Continued investigation of mindfulness interventions of varying durations and the use of longitudinal designs will be important to examine optimal doses required to achieve clinically significant outcomes within clinical populations. This is particularly important given propositions that high trait anxious individuals differ in the way that that they exert top-down regulation (e.g., Ansari & Derakshan, 2011; Basten, Stelzel, & Fiebach, 2011) and the possibility that cognitive and psychological characteristics such as attentional control (Hölzel, Lazar et al., 2011) and rumination (Heeren & Philippot, 2011; Schmertz, Masuda & Anderson, 2012) may mediate the effects of mindfulness.

Moreover, this sample largely consisted of psychology undergraduate students (89%). It is possible that psychology students may have experienced greater confidence in this intervention given that it is a relatively new and popular psychological approach, thereby resulting in expectancy effects. Furthermore, 46% of the sample was accurately able to report whether they had inhaled CO_2 or air; thus demand characteristics may have confounded the results. This study used an opportunistic and self-selecting sample and therefore there is the potential for confounds associated with self-selection and motivational biases. Alternatively, it is possible that participants may not have engaged fully throughout the intervention. Recent findings have highlighted that task effort and compliance is important (Jensen et al., 2011). This study also employed a single-blind design, in which participants, but not the researchers, were unaware of the experimental condition. Although care was taken to ensure that the researchers facilitated the study in an equable manner by adherence to a strict protocol, it is possible that researchers' expectations could have influenced outcome. Responder bias and social desirability bias was also not assessed in this study. It is possible that these biases occurred, although scores obtained on the PANAS-P suggest that this is not the case. Furthermore, mindfulness did not lead to general reductions in anxiety, but instead CO_2-induced anxiety specifically.

Responder bias was not directly assessed or manipulated within this study but should be an important consideration for future research. Subsequent studies should therefore use double-blind methodologies with divergent samples and consider the use of incentive designs. Future research could also include measures of social desirability, such as the Brief Marlow-Crowne Social Desirability Scale (Strahan & Gerbasi, 1972) or the Balanced Inventory of Desirable Responding (Paulhus, 1984).

4.3.2 Methodological design. The evidence-base is highly influenced by uncontrolled research that does not account for the progression of time, demand characteristics, placebo effects and other associated potential confounds. This study usefully employed a control condition of relaxation; however the intervention may have been structurally different with regard to stimulation, cognitive demand and response preparation. Moreover, participants were given no instructions regarding the nature of their relaxation and although data on participants' use of this time was not collected, it is possible that there was significant variation within this condition. Further research is required with active control groups, such as non-mindfulness stress reduction (Jensen et al., 2011) and sham mindfulness (Zeidan, Johnson, Gordon, et al., 2010) groups that have been incorporated within recent studies. The inclusion of participants matched on a range of demographic variables such as age, gender, ethnicity, socio-economic status, psychological characteristics and educational attainment will also be useful. The inclusion of active control groups that are conceptually similar and structurally comparable with regards to intensity, duration, instructor qualities, cognitive demand, modality and delivery will be important since there is some evidence of attenuated effects sizes when mindfulness has been examined within rigorously controlled methodologies (e.g., Bohlmeijer et al., 2010).

Such designs may also allow firmer conclusions to be made regarding the benefits of mindfulness through specific rather than non-specific effects.

This study examined distilled applications of mindfulness, in contrast to the typical evaluation of mindfulness practices within interventions such as MBSR and MBCT that include additional treatment components. Interventions such as MBSR and MBCT constitute partially overlaying but separate mindfulness applications, thereby reducing the validity of comparisons between them and discriminations between the effects of mindfulness from other elements. Therefore, an important future direction will be the continued use of dismantling designs and meditational analyses to compare applications of FM and OMi and other different styles with disparate foci, such as divergent external stimuli or internal physiological, cognitive or emotional events. A greater understanding of the differential effects of disparate practices will (i) promote a greater understanding of the components developed by different techniques, (ii) enable the assessment of the differential effectiveness of practices within different populations and settings and (iii) contribute to an understanding of mindfulness mechanisms that become more or less relevant within different contexts. Direct examination of the effects of mindfulness variants on constructs hypothesised as predominant mechanisms of mindfulness will be important. The effects of mindfulness variations on attention may be a useful starting point since conceptual accounts and empirical evidence consistently support the role of attention as both a mechanism of mindfulness (e.g., Hölzel, Lazar, et al., 2011) and in the aetiology of anxiety disorders (e.g., Cisler & Koster, 2010). Such research will be important to progress from descriptive to explanatory accounts of mindfulness.

4.3.3 Outcome measures. The use of outcome measures commonly employed within the research literature enabled comparisons with other studies.

However, the validity of self-report measures of mindfulness has been questioned by suggestions that participants may not be able to reliably report on the degree and quality of their mindfulness (e.g., Coffey, Hartman, & Fredrickson, 2010; Grossman, 2011). Furthermore, continued theoretical, conceptual and empirical consideration is necessary to address suggestions that dispositional mindfulness within novice practitioners may be more accurately represented as state mindfulness (Schmertz, Anderson, & Robins, 2009). Mind-wandering is proposed as a state approximately opposite to mindfulness and describes attention shifts and consequential inattentive representations of the external environment and task failures (Davidson, 2010). Further examination of the association between existing measures of mindfulness and temporally stable electrophysiological, hemodynamic and behavioural correlates of mind-wandering may usefully contribute to the validation of self-report measures (Davidson, 2010). Additionally, few studies have directly examined the physiological effects of brief mindfulness practice on anxiety; the continued collection of physiological data will be important to supplement self-report measures and contribute to our understanding of the mechanisms of mindfulness. It will also be important to assess broader outcomes, such as clinically significant change, behavioural indicators and the continued use of mindfulness. There is some evidence for the continued practice of mindfulness following engagement in mindfulness interventions (Miller, Fletcher, & Kabat-Zinn, 1995; Piet et al., 2010) so it is important to examine what variables moderate continued practice. In this respect, a variety of research designs and methodologies, including quantitative, qualitative, naturalistic and neuroimaging studies, may be useful to provide converging evidence.

5.0 Conclusion

This study was the first to directly compare the prophylactic and differential effects of brief FM and OMi practice on state anxiety, affect and autonomic arousal as induced by the 7.5% CO_2 challenge. Consistent with previous findings, this research provided further empirical validation of the 7.5% challenge as a novel experimental model of GAD and evidence of the beneficial effects of mindfulness inductions on anxious and affective symptomatology. Results indicate that participants who engaged in FM or OMi reported significantly larger reductions in state anxiety and negative affect than those in a relaxation control group. Non-significant differences between objective levels of stress across groups suggest that these effects were not solely meditated by relaxation or reduced arousal and therefore contribute to the growing body of evidence that suggests that mindfulness exerts its benefits through specific effects. This study did not support enhanced positive affect following brief mindfulness practice; this is generally consistent with other research that has examined mindfulness inductions of a similar duration (Arch & Craske, 2006; Erisman & Roemer, 2010; Kiken & Shook, 2011). As indicated by case-controlled meditation research (e.g., Rubia, 2009) and correlational findings (Jha et al., 2010), physiological changes and improvements in positive mood are more likely to be observed following more extensive practice.

This study did not observe differential effects of 10-minute FM and OMi inductions. The lack of distinction between these styles within this study is likely to be an artefact of methodological design and reflect that the attainment of open mindfulness may be contingent on the accomplishment of skills within narrow-focused mindfulness (e.g., Lutz, Brefczynski-Lewis, et al., 2008; Lutz, Dunne, et al., 2008). It is probable that further practice is required to facilitate valid comparisons between FM and OMi. However, preliminary evidence of the differential efficacy and effectiveness of disparate meditation styles (Barnhofer et al., 2010; Grant & Rainville, 2009; Manna et al., 2010; Perlman et al., 2010; Schoormans & Nykliček, 2011) suggests that further research is warranted. Continued theoretical and conceptual consideration and empirical research in a number of directions is required to verify the available findings, examine differences between mindfulness variants and establish the specificity and generalisability of particular practices in the treatment of different disorders. It is anticipated that progression within these areas will also contribute to a further understanding of the mechanisms of mindfulness.

These findings have important clinical implications. The results contribute to the growing evidence-base suggesting that brief mindfulness inductions that are cost-effective, time-efficient, trans-diagnostic and viable within the NHS can beneficially reduce anxious and affective symptomatology. The propensity for mindfulness interventions to be applied at all levels of a stepped-care approach, as an adjunct to existing treatments or as a stand-alone intervention and in various delivery formats, is in line with national imperatives (Department of Health, 2011) and key priorities for the implementation of mental health services (NICE, 2011). Moreover, the continued validation, development and application of mindfulness will be important to treat symptoms of anxiety and depression that continue to be prevalent, persistent and associated with significant adversity (Department of Health, 2011). It is anticipated that these opportunities present exciting research avenues that will allow mindfulness to be extended beyond its existing parameters.

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List of Appendices

Appendix A

Flow Chart of Study Procedures and Task

Pre-test telephone screening following verbal consent

↓

Follow-up screening on the day of testing following verbal and written informed consent

↓

Baseline measures collected
Trait anxiety (STAI-T), worry (PSWQ) & anxiety sensitivity (ASI) | Dispositional mindfulness (MAAS; FFMQ) | Attentional control (ACS)

↓

Participants randomised to experimental and control groups

↓

Experimental groups		Control
Focused Mindfulness (FM)	**Open Mindfulness (OMi)**	**Relaxation**
1. Pre-test measures collected State anxiety (STAI-S) | State mood (PANAS) | Autonomic arousal (systolic BP, diastolic BP & heart rate)	**1. Pre-test measures collected** State anxiety (STAI-S) | State mood (PANAS) | Autonomic arousal (systolic BP, diastolic BP & heart rate)	**1. Pre-test measures collected** State anxiety (STAI-S) | State mood (PANAS) | Autonomic arousal (systolic BP, diastolic BP & heart rate)
2. Mindfulness practice Participants listen to a 10-minute audio-recording of guided FM	**2. Mindfulness practice** Participants listen to a 10-minute audio-recording of guided OMi	**2. Relaxation** Unguided 10-minute relaxation period
3. Inhalation of 7.5% CO_2-enriched medical air/usual medical air (20 minutes) Participants completed a 10-minute computerised antisaccade task[a] during each inhalation	**3. Inhalation of 7.5% CO_2-enriched medical air/usual medical air (20 minutes)** Participants completed a 10-minute computerised antisaccade task[a] during each inhalation	**3. Inhalation of 7.5% CO_2-enriched medical air/usual medical air (20 minutes)** Participants completed a 10-minute computerised antisaccade task[a] during each inhalation
4. Post-test measures collected STAI-S | PANAS | Systolic & diastolic BP and heart rate	**4. Post-test measures collected** STAI-S | PANAS | Systolic & diastolic BP and heart rate	**4. Post-test measures collected** STAI-S | PANAS | Systolic & diastolic BP and heart rate
5. Rest interval (25 minutes)	**5. Rest interval (25 minutes)**	**5. Rest interval (25 minutes)**
Steps 1-5 repeated (with inhalation counterbalanced according to prior inhalation)	**Steps 1-5 repeated** (with inhalation counterbalanced according to prior inhalation)	**Steps 1-5 repeated** (with inhalation counterbalanced according to prior inhalation)

↓

Verbal and written de-brief provided to all participants

↓

Telephone contact with participants within 24 hours of study participation to confirm their safety and well-being

Note. STAI-T = State-Trait Anxiety Inventory-Trait subscale; PSWQ = Penn State Worry Questionnaire; ASI = Anxiety Sensitivity Index; MAAS = The Mindfulness Attention Awareness Scale; FFMQ = Five Facet Mindfulness Questionnaire; ACS = Attentional Control Scale; STAI-S = State-Trait Anxiety Inventory-State subscale; PANAS = Positive and Negative Affect Schedule; BP = Blood pressure.
[a] During the antisaccade task, participants are asked to visually fixate on a central stimulus which is replaced by a sudden onset target that appears to the left or the right. Participants are asked to direct their gaze in the opposite direction to the target instead of looking at the target itself (please see Garner et al., 2011 for further details of the antisaccade task). This data was collected to be reported elsewhere by different authors.

Appendix B

Telephone-Administered Neuropsychiatric Screening Interview

Telephone-administered neuropsychiatric screening interview	
Researcher initials	
Subject identifier	
Subject initials	
Date	

1. Demographic details	
Name	
Gender	☐ Male ☐ Female
Race	☐ White ☐ Mixed ☐ Asian or Asian British ☐ Black or Black British ☐ Chinese ☐ Other
D.O.B	DD/MM/YYYY
Address	
Telephone (Home/Mobile/Work)	
Email	
Height	
Weight	
Body Mass Index (BMI)	
Availability	
Where did you hear about this study?	

2. Caffeine consumption	
Do you consume caffeinated drinks?	☐ Yes ☐ No
If yes, number of cups/day	☐ Coffee ☐ Tea ☐ Carbonated soft drink containing caffeine ☐ Cocoa Total:

3. Alcohol consumption	
Do you consume alcohol?	☐ Yes ☐ No
If yes, number of units/week	☐ Wine ☐ Beer ☐ Spirits Total:

4. Smoking	
Do you smoke?	☐ Yes ☐ No
If yes, do you smoke on a daily basis?	☐ Yes ☐ No

5. Medical history	
Are you alcohol/drug dependent? If yes, please specify	☐ Yes ☐ No
Do you suffer from heart/lung disease? If yes, please specify	☐ Yes ☐ No
Do you have a family history of cardiovascular or respiratory disease? If yes, please specify	☐ Yes ☐ No
Do you suffer from thyroid disease?	☐ Yes ☐ No
Do you suffer from diabetes?	☐ Yes ☐ No

Do you suffer from migraines? If yes, do you receive treatment for migraines?	☐ Yes ☐ No ☐ Yes ☐ No
Do you suffer from hyperventilation attacks?	☐ Yes ☐ No
Do you suffer from asthma?	☐ Yes ☐ No
Do you suffer from high blood pressure?	☐ Yes ☐ No
Do you currently receive any medication? If yes, please specify	☐ Yes ☐ No
Do you have a history of drug/food allergy? If yes, please specify	☐ Yes ☐ No
Do you suffer from any psychiatric illness (e.g. anxiety, panic, depression etc.?) If yes, please specify	☐ Yes ☐ No
Do you suffer from epilepsy? If yes, please specify	☐ Yes ☐ No
Do you currently have a General Practitioner?	☐ Yes ☐ No
Have you participated in any drug trials? If yes, please specify	☐ Yes ☐ No
Do you use contraception? If yes, please specify	☐ Yes ☐ No
Are you currently taking medication? If yes, please specify	☐ Yes ☐ No
Is there any other relevant information that you wish to provide? If yes, please specify	☐ Yes ☐ No

6. Prior experience of mindfulness	
Have you heard of mindfulness?	☐ Yes ☐ No
Do you practice mindfulness?	☐ Yes ☐ No
Have you ever practiced mindfulness?	☐ Yes ☐ No
If yes to the preceding two questions, please specify	

Appendix C

Follow-Up Neuropsychiatric Screening Interview

Follow-up neuropsychiatric screening interview	
Researcher initials	
Subject identifier	
Subject initials	
Date	

1. Alcohol breath test	
Time	HH:MM
Result	☐ Positive ☐ Negative
Stop screening if test is positive.	

2. Caffeine consumption	
Have you consumed any caffeinated drinks in the past 12 hours?	☐ Yes ☐ No
If yes, give time now	HH:MM

3. Medication	
Have you used any medication since the telephone-administered screening?	☐ Yes ☐ No
If yes, please specify	

4. Current health	
Are you currently healthy? If no, please specify	☐ Yes ☐ No
Have you been ill within the past 7 days? If yes, please specify	☐ Yes ☐ No

5. Cardiovascular assessment: Blood pressure and heart rate			
Time	Systolic BP (mm Hg)	Diastolic BP (mm Hg)	Pulse rate (beats/min)
HH:MM			

6. Pregnancy

The effects of 7.5% CO_2 inhalation on an unborn child or breast milk are currently unknown. Therefore, you should not take part in this study if you are pregnant or breast-feeding.

Therefore, by signing this declaration you are confirming that one of the following applies:

I am using a reliable form of contraception*.
I have not had unprotected sex since my last menstrual period.
I have not had unprotected sex since taking emergency contraception.
I have been sterilised or have reached the menopause.

*i.e. one of the following: (i) barrier methods and spermicide, (ii) oral contraception, (iii) inauterine contraception, (iv) injectable contraception or (v) contraceptive patch.

Participant signature:

Print name:

Date:

7. Neuropsychiatric interview[10]		
Instructions: When 'yes' the subject should be further discussed to determine whether inclusion is appropriate.		
8a. Depression		
Have you been consistently depressed or down, most of the day, nearly every day, for the past two weeks?	☐ Yes	☐ No
In the past two weeks, have you been less interested in most things or less able to enjoy the things you used to enjoy most of the time?	☐ Yes	☐ No
Have you felt sad, low or depressed most of the time for the last two years?	☐ Yes	☐ No
Have you ever made a suicide attempt?	☐ Yes	☐ No
8b. Mania		
Have you ever had a period of time when you were feeling 'up' or 'high' or so full of energy or full of yourself that you got into trouble, or that other people thought that you were not your usual self? (Do not consider times that you were intoxicated on drugs or alcohol).	☐ Yes	☐ No
Are you currently feeling 'up' or 'high' or full of energy? If further clarification is needed: By 'up' or 'high' I mean, having elated mood, increased energy, needing less sleep, having rapid thoughts, being full of ideas, having an increase in productivity, motivation, creativity or impulsive behaviour.	☐ Yes	☐ No
Have you ever been persistently irritable, for several days, so that you had arguments or verbal or physical fights or shouted at people outside your family? Have you or others noticed that you have been more irritable or over-reacted, compared to other people, even in situations that you felt were justified?	☐ Yes	☐ No
Are you currently feeling persistently irritable?	☐ Yes	☐ No
8c. Anxiety		
Have you, on more than one occasion, had spells or attacks when you suddenly felt anxious, frightened, uncomfortable or uneasy, even in situations where most people would not feel that way? Did the spells peak within 10 minutes?	☐ Yes ☐ Yes	☐ No ☐ No
Do you feel anxious or uneasy in places or situations where you might have a panic attack or the panic-like symptoms we just spoke about, or where help might not be available or escape might be difficult: like being in a crowd, standing in a line (queue), when you are alone away from home or alone at home, or when crossing a bridge, travelling in a bus, train or car?	☐ Yes	☐ No
In the past month, were you fearful or embarrassed being watched, being the focus of attention, or fearful of being humiliated? This includes things like speaking in public, eating in public or with others, writing whilst someone watches or being in social situations.	☐ Yes	☐ No
Have you worried excessively or been anxious about several things over the past 6 months?	☐ Yes	☐ No
Are these worries present most days?	☐ Yes	☐ No
8d. Obsessive compulsive disorder		
In the past month, have you been bothered by recurrent thoughts, impulses, or images that were unwanted, distasteful, inappropriate, intrusive or distressing? (For example, the idea that you were dirty, contaminated or had germs, or fear of contaminating others, or fear of harming someone even though you didn't want to, or fearing you would act on some impulse or fear or superstition that you would be responsible for things going wrong, or obsessions with sexual thoughts, images or impulses, or hoarding, collecting, or religious obsessions).	☐ Yes	☐ No
Do not include simply excessive worries about real-life problems, obsessions directly related to eating disorders, sexual deviations, pathological gambling or alcohol or drug abuse.		

[10] Based on screening questions in the Mini International Neuropsychiatric Interview (MINI; Sheehan et al., 1998).

8e. Post-traumatic stress disorder	
Have you ever experienced or witnessed or had to deal with an extremely traumatic event that included actual or threatened death or serious injury to you or someone else? (Examples of traumatic events include: serious accidents, sexual or physical assault, a terrorist attack, being held hostage, kidnapping, fire, discovering a body, sudden death of someone close to you, war, or natural disaster.	☐ Yes ☐ No
Did you respond with intense fear, helplessness or horror?	☐ Yes ☐ No
During the past month, have you re-experienced the event in a distressing way (such as, dreams, intense recollections, flashbacks or physical reactions)?	☐ Yes ☐ No
8f. Family history of psychiatric illness	
Are you aware of any family member that has experienced a psychiatric illness, including panic attacks? If yes, please specify	☐ Yes ☐ No
8g. Addiction	
In the past twelve months, have you had 3 or more alcoholic drinks within a 3 hour period on 3 or more occasions?	☐ Yes ☐ No
Have you ever got into trouble by the use of alcohol and/or have you ever been tackled by someone about your drinking behaviour?	☐ Yes ☐ No
In the past twelve months, did you take any of the following drugs more than once, to get 'high', to feel better or to change your mood?	☐ Yes ☐ No

Stimulants	☐ Amphetamine ☐ 'Speed' ☐ Crystal methadone ☐ Dexedrine ☐ Ritalin ☐ 'Rush'
Cocaine	☐ Snorting ☐ Intravenous ☐ Freebase ☐ 'Crack' ☐ 'Speedball'
Narcotics	☐ Heroin ☐ Morphine ☐ Opium ☐ Dilaudid ☐ Demerol ☐ Methadone ☐ Codeine ☐ Percodan ☐ Darvon
Hallucinogens	☐ LSD (Acid) ☐ Mescaline ☐ PCP ('Angel dust') ☐ 'Mushrooms' ☐ XTC ☐ MDA ☐ Peyote ☐ Psilocybin ☐ STP
Inhalants	☐ Glue ☐ Ethylchloride ☐ Laughing gas ☐ Amyl or butyl nitrate ('poppers')
Marijuana	☐ Hashish (hasj) ☐ THC ☐ Weed ☐ 'Pot' ☐ 'Grass' ☐ 'Reefer'
Tranquilizers	☐ Quaalude ☐ Secdondal ('reds') ☐ Valium ☐ Xanax ☐ Librium ☐ Ativan ☐ Dalmane ☐ Halcion ☐ Barbiturates ☐ Miltown
Miscellaneous	☐ Steroids ☐ Non-prescription sleep or diet pills ☐ GHB ☐ Other
If 'yes' to any of the drugs listed, note the date of most recent use below:	

9. Eligibility check	
Currently healthy	☐ Yes ☐ No
Age between 18-55 years (inclusive)	☐ Yes ☐ No
Blood Pressure < 140/90	☐ Yes ☐ No
Heart Rate between 50-90	☐ Yes ☐ No
BMI between 18–28 kg/m^2	☐ Yes ☐ No
If female, not pregnant or breastfeeding Using adequate contraception/abstinence	☐ Yes ☐ No ☐ Yes ☐ No
No history of alcohol dependency Consumption of ≤ 50 alcoholic units/week (males) and ≤ 35 alcoholic units/week female) Negative alcohol breath test	☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No

No history of drug dependency/current use	☐ Yes ☐ No
Consumption ≤ 8 caffeinated drinks/day	☐ Yes ☐ No
Does not smoke on a daily basis	☐ Yes ☐ No
No Current/history of: Personal/familial psychiatric illness (including panic attacks), cardiovascular/respiratory illness Migraines requiring treatment Hyperventilation attacks	☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No
No current medical illness or clinically significant acute illness within 7 days prior to the study	☐ Yes ☐ No
No medication in the last 8 weeks Allowable exceptions: local treatment, oral or injectable contraception, stable [≥ 3 months] HRT and occasional aspirin or paracetamol use	☐ Yes ☐ No
No prior experience of mindfulness or meditation.	☐ Yes ☐ No

Appendix D

Verification of Ethical Approval from the School of Psychology Ethics Committee and the Research Governance Office, University of Southampton

Submission Number: 742
Submission Name: Effects of attention training on subjective, autonomic and neuropsychological response to carbon dioxide challenge
This email is to let you know your submission was approved by the Ethics Committee.

You can begin your research unless you are still awaiting specific Health and Safety approval (e.g. for a Genetic or Biological Materials Risk Assessment)

Click here to view your submission

ERGO : Ethics and Research Governance Online
http://www.ergo.soton.ac.uk

DO NOT REPLY TO THIS EMAIL

Appendix E

Participant Information Sheet and Consent Form

Study ID = 742: version 1, 4/10/11

INFORMATION FOR PARTICIPANTS

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.

EFFECTS OF ATTENTION TRAINING ON SUBJECTIVE, AUTONOMIC AND NEUROPSYCHOLOGICAL RESPONSE TO CARBON DIOXIDE CHALLENGE

Principal Investigator: Dr Matt Garner

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part and remember that your participation is voluntary.

What is the purpose of the research study?

A recent World Health Organisation study reports that anxiety disorders are more common than many other psychiatric disorders and that because they often result in impairment of daily life, are among the most burdensome of diseases. Generalised anxiety disorder (GAD) is a common anxiety disorder, yet it is often not diagnosed or treated properly. Patients who suffer from GAD experience excessive anxiety and worry, and a range of symptoms including muscular tension, restlessness, dizziness, feelings of unreality, difficulty in concentrating, and a feeling of being 'keyed up', often with increases in heart rate, blood pressure and sweating.

If there was a human model of GAD, (that is, a way of temporarily producing some of the symptoms of GAD, but in a healthy person) it could be used to discover new and more effective treatments and help us to understand what is happening in the body. To be effective, any potential model would need to reliably produce anxiety in healthy people and the degree of anxiety should be repeatable and measurable.

We have been working on the development of a model of GAD using the inhalation of 7.5% carbon dioxide (CO_2) for 20 minutes. In healthy volunteers this makes some people feel anxious and tense and reduces feelings of being relaxed and happy. It also increases blood pressure and heart rate measures. All the effects of CO_2 are different from the inhalation of normal room air and we believe that this model could be used to explore how and whether treatments work in GAD.

So that we can further investigate the 7.5% CO_2 model of GAD, we examine variables that might alter individuals' response experience of CO2 inhalation. We plan to do this by recruiting healthy male and female volunteers, aged between 18 and 55 years and randomising them to one of four experimental conditions in which they complete different tasks before completing the CO_2 inhalation.

Why have I been chosen?

You have been invited to participate since you have enquired about our advertised studies.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form prior to any further participation. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect your future or be held against you in any way.

What does the research study involve?

Before entering the research study the researchers will contact you and ask specific questions about your medical and psychiatric history, to check that you are fit to take part in the study. This will take about 10 minutes, will be arranged at your convenience and can be completed over the phone if helpful. All information will remain confidential.

You should be generally healthy, have no history of or current asthma or migraines, and have no present or past anxiety disorder or other mental health problem. You should not take part if a close member of your family suffers from regular panic attacks or has been diagnosed with panic disorder. You should not take part if you or your family have experienced cardiovascular problems. Your alcohol intake should not be more than 50 units per week (male) or 35 units per week (female). You should not be a regular smoker. No other medication should have been used in the preceding 8 weeks, apart from occasional aspirin or paracetamol, or local treatments. Females should be using adequate methods of contraception and should not be pregnant or breast feeding, or considering becoming pregnant. Your eligibility according to the above will be determined over the course of the telephone screening (10 min) and pre-test interview (10 min).

If you are found to meet our list of entry criteria, then you will be invited to complete the study.

What do I have to do on the study day?

YOUR TIME COMMITMENT IN THE RESEARCH STUDY IS AS FOLLOWS:

Prior to the testing session you should refrain from alcohol for 36 hours. You should not drink any caffeinated drinks after midnight prior to the day of testing. This is because alcohol and caffeine have effects of their own on blood pressure and heart rate measurements and alcohol may enhance the effects of the gas. However, exception from this is if you regularly ingest caffeine in the morning. If this is the case, you should have your usual caffeinated drink to avoid withdrawal effects during the study. You should not be a regular (i.e., daily) smoker and should not have smoked within 12 hours of the study session.

You will be required to attend one test session of approximately 3 hours. You will remain seated in a comfortable position throughout the testing session. During the testing session, measurements of your blood pressure and heart rate will be periodically taken using six peripheral (i.e. non-invasive) skin-sensors. You will complete some questionnaires to measure how you are feeling.

Measurements will be taken shortly after you arrive and once you are comfortable. During the test session you will undergo two inhalation procedures each of 20-minutes duration. The physiological measures (i.e., heart rate, blood pressure) and questionnaire measurements will be taken before and after each inhalation, and there will be a rest period between inhalations. During the two inhalation procedures you will complete a short computerized task that requires you to press buttons as quickly and accurately as you can. In each task we will place a skin surface electrode on your left and right temple to measure your eye-muscle activity, and will place two skin surface electrodes on the left, and right-hand side of your scalp to record electrical activity in your left and right hemispheres. In one of the tasks you will be presented with a set of widely used experimental emotional pictures, some of which you may find unpleasant. Before you agree to participate you will have the opportunity to view example emotional pictures. Please remember that you are free to withdraw from the study at any time.

The 20-minute gas inhalations will be administered through a mask, which covers your mouth and nose. This will be fitted prior to inhalation of the gas to enable you to become accustomed to wearing it. You will then wear the mask during the inhalation.

Any effects of the gas inhalation are temporary, and at the end of the study session you will remain in the testing room until you feel that any effects of the gas have worn off. We will contact you the day after the study to check that you are healthy and well.

What are the gas mixtures being delivered?

The 7.5% CO_2 gas is a mixture of carbon dioxide and air, with the air containing the usual amount of oxygen. The air will be normal air that is administered via a mask in the same way as the CO_2.

What are the side effects of the gas treatments?

CO_2 inhalation may cause feelings of anxiety or unpleasantness. Other physiological effects that may occur include racing of heart, dizziness, pins and needles, and breathlessness. Some people also experience a mild headache afterwards.

People experience and describe the effects of inhaling 7.5% CO_2 gas in different ways, and there is no way of knowing in advance how you will respond. Some people do not notice it at all, and some experience more marked anxiety. Most people will notice some effects, and if you do not like the effects, you can ask to stop. These feelings should be short-lived (resolve within 5 minutes) and will not cause any lasting harm.

The researchers will remain near you at all times and will offer reassurance if necessary. If you feel uncomfortable breathing the gas at any time during the procedure you may indicate that you wish the procedure to stop.

What are the possible disadvantages and risks of taking part?

Pregnant women should not take part in this study, and neither should women who plan to become pregnant. All women will therefore be asked to answer six short questions about their use of contraception to exclude the possibility of pregnancy.

What are the possible benefits of taking part?

You will not expect to directly benefit from taking part in this research study and your participation is voluntary. However, the information we get from this study may help us to understand and treat patients with anxiety disorders in the future.

What if new information becomes available?

We do not expect any new information about the effects of the inhalation procedure to become available, but if this happens this information will be passed on to you immediately.

Will my taking part in this study be kept confidential?

All data is anonymised and confidential. You will be assigned a unique participant number that will be used to identify your data – your name will not be linked with or stored with any of your data. Any information and research study documentation taken for this research study will remain confidential and will be available only to the principal investigator and members of his research team directly involved in the project.

What will happen to the results of the research study?

When the study has been completed, we shall analyse the data and report the findings. This will be reported in an appropriate scientific journal or presented at a scientific meeting. You would not be identified in any way and if you would like a copy of the final paper, you may request this.

Who is organising and funding the research?

The study is being organised and sponsored by the University of Southampton.

Who has reviewed the study?

The study has received approval from an appropriate ethics panel within the University of Southampton, and the University of Southampton Research Governance Office.

Who can I contact for further information?

For further queries, please contact Dr Matt Garner or Prof David Baldwin (see below).

Dr Matt Garner	Prof David Baldwin
m.j.garner@soton.ac.uk	dsb1@soton.ac.uk
02380825539	

If you participate in this study you will be given a copy of this information sheet and a signed consent form to keep.

UNIVERSITY OF Southampton

CONSENT FORM (Study ID = 742: version 1, 4/10/11)

Study title: **EFFECTS OF ATTENTION TRAINING ON SUBJECTIVE, AUTONOMIC AND NEUROPSYCHOLOGICAL RESPONSE TO CARBON DIOXIDE CHALLENGE**

Principal Investigator: Dr Matt Garner:
Research Assistants: Ben Ainsworth, Verity Pinkney, Joanna Miller, Jemma Marshall, Elizabeth Sargeant

Study reference: 742
Ethics reference: 742

Please initial the box(es) if you agree with the statement(s):

I have read and completed the information sheet (version 1, 4/10/11) and have had the opportunity to ask questions about the study ☐

I agree to take part in this research project and agree for my data to be used for the purpose of this study ☐

I understand my participation is voluntary and I may withdraw at any time without my legal rights being affected ☐

Name of participant (print name)…………………………………………………

Signature of participant……………………………………………………………..

Date……………………………………………………………………………………

Name of experimenter (print name)…………………………………………………

Signature of experimenter……………………………………………………………..

Date……………………………………………………………………………………

[v1] [4/10/11]

Appendix F

Written De-Briefing Sheet: Participants Excluded Following Screening

Debrief (Version 1.0) 4/10/11 Study ID: 742

EFFECTS OF ATTENTION TRAINING ON SUBJECTIVE, AUTONOMIC AND NEUROPSYCHOLOGICAL RESPONSE TO CARBON DIOXIDE CHALLENGE

Thank you for your interest and participation in the screening stage of this experiment. Unfortunately, on this occasion you have not met all of the study inclusion criteria and therefore your participation within subsequent stages of this research will not be required.

Throughout the screening you were asked various questions regarding your physical and mental health. Should you have any concerns or wish to further discuss any details, the following contacts may be helpful to you: your General Practitioner, NHS Direct, Student Services and/or your Personal Tutor.

Furthermore if you have any concerns or queries regarding any aspect of your participation in this study then please feel free to contact Dr Matt Garner at m.j.garner@soton.ac.uk or on 02380 595926 and he will be happy to discuss these with you.

If you have questions about your rights as a participant in this research, or if you feel that you have been placed at risk, you may contact the Chair of the Ethics Committee, Psychology, University of Southampton, Southampton, SO17 1BJ. Phone: 02380 595578.

Appendix G

Written De-Briefing Sheet Following Full Participation

Debrief (Version 1.0) 4/10/11 Study ID: 742

EFFECTS OF ATTENTION TRAINING ON SUBJECTIVE, AUTONOMIC AND NEUROPSYCHOLOGICAL RESPONSE TO CARBON DIOXIDE CHALLENGE

Thank you for taking part in our experiment.

Study background: Inhalation of 7.5% CO_2 increases anxiety and autonomic arousal in humans and provides a novel experimental model of anxiety in healthy humans. This model is well placed to evaluate promising treatments for anxiety, including psychological treatments and pharmacological drug treatments.

Our study examined the extent to which different psychological interventions offered protection against CO_2-increased anxiety and autonomic arousal (e.g., heart rate, blood pressure, skin conductance). You were randomised to one of several psychological intervention groups: 1) attentional bias modification (in which your attention was trained away from threat stimuli), 2) narrow-focus mindfulness training, 3) open-focused acceptance/mindful training, or 4) control (no intervention).

If you are interested in finding out more about the rationale behind this research and methods used in this project please see the references below:

1. Bailey, J. E., Argyropoulos, S. V., Kendrick, A. H., & Nutt, D. J. (2005). Behavioral and cardiovascular effects of 7.5% CO_2 in human volunteers. *Depression and Anxiety, 21*(1), 18-25.

2. Ziemann, A. E., Allen, J. E., Dahdaleh, N. S., Drebot, II, Coryell, M. W., Wunsch, A. M., et al. (2009). The amygdala is a chemosensor that detects carbon dioxide and acidosis to elicit fear behavior. *Cell, 139*(5), 1012-1021.

3. Garner, M., A. Attwood, et al. (2011). Inhalation of 7.5% Carbon dioxide increases threat processing in humans. *Neuropsychopharmacology 36*(8), 1557-1562.

During this study we have asked you to reflect on certain aspects of your physical and mental health. If at any point during your studies you become concerned about your mental or physical health then please contact your General Practitioner.

As noted in the information sheet – individuals vary in their response to the inhalation of CO_2 with most individuals feeling completely normal by the end of the experimental session. Occasionally individuals report a mild headache for a short time afterwards. In the unlikely event that you feel unwell please contact your General Practitioner or NHS Direct on 0845 4647 as per usual.

Finally, if you have more general worries during your time as a student in Southampton then please also be aware that Student Services or your personal tutor are happy to provide support and advice.

Furthermore if you have any concerns or queries regarding any aspect of your participation in this study then please feel free to contact Dr Matt Garner at m.j.garner@soton.ac.uk or on 02380 595926 and he will be happy to discuss these with you.

A member of the research team will phone you tomorrow to check that you have not experienced any adverse events following your participation, and to discuss any additional queries that you might have.

Thank you for your participation in this research.

Signature ________________________________ Date________________________________

Name ________________________________

If you have questions about your rights as a participant in this research, or if you feel that you have been placed at risk, you may contact the Chair of the Ethics Committee, Psychology, University of Southampton, Southampton, SO17 1BJ. Phone: 02380 595578.

Appendix H

Statistical Equations Used to Calculate Cohen's *d* Effect Sizes

Cohen's *d* (1992) effect sizes were calculated by dividing mean differences by their pooled standard deviation (s).

$$d = \frac{\bar{x}_1 - \bar{x}_2}{s}$$

Pooled standard deviations were calculated according to the definition provided by Hartung, Knapp, & Sinha (2008):

$$s = \sqrt{\frac{(n_1 - 1)\, s_1^2 + (n_2 - 1)\, s_2^2}{n_1 + n_2}}$$

$$s_1^2 = \frac{1}{n_1 - 1} \sum_{i=1}^{n_1} \left(x_{1,i} - \bar{x}_1\right)^2$$

$$s_2^2 = \frac{1}{n_2 - 1} \sum_{j=1}^{n_2} \left(x_{2,j} - \bar{x}_2\right)^2$$

Glossary

Acceptance and commitment therapy (ACT; Hayes, Strosahl, & Wilson, 1999)	ACT is a 3rd wave cognitive-behavioural psychotherapy. ACT is typically delivered in individual formats and uses acceptance and mindfulness practices alongside commitment and behavioural strategies.
Amygdala	The amygdala is located in the medial temporal lobe and is considered to be part of the limbic system. The amygdala is predominantly involved in the processing and memory of emotional reactions (e.g., facilitated attention to and delayed disengagement from threat) and is conceptualised to be down-regulated and inhibited by the prefrontal cortex during emotion regulation. This process is thought to suppress fear and increase control over behavioural responses.
Anterior cingulate cortex (ACC)	The ACC is located at the front of the cingulate cortex and is involved in a range of autonomic functions, including the regulation of heart rate and blood pressure. The ACC is also important for reward anticipation, decision-making, empathy, emotion and threat processing. Evidence suggests that the ACC facilitates executive attention by detecting conflicts arising from incompatible information processing streams and forms a network with the fronto-insular cortex that supports shifts in activation of different networks, thereby facilitating responses to cognitively challenging events.
Cognitive behavioural therapy (CBT)	CBT is a time-limited, structured intervention that addresses psychological difficulties maintained by problematic thoughts and beliefs. Cognitive and behavioural strategies, including activity scheduling and behavioural experiments, are employed. CBT can be delivered in individual and group formats.
Default mode network (DMN)	The DMN is an anatomical network that is active during wakeful rest (when an individual is not engaged or interacting with stimuli). Subsystems include regions of the medial temporal lobe, medial prefrontal cortex, the posterior cingulate cortex, adjacent precuneus and the lateral, medial and inferior parietal lobe. The DMN has been implicated in the generation of spontaneous and stimulus-independent thought during mind-wandering and the integration of self-referential information into autobiographical memory.

Dialectical behaviour therapy (DBT; Linehan, 1993)	DBT is a system of therapy originally developed as a treatment approach for borderline personality disorder. DBT is a 3rd wave cognitive-behavioural approach that can be applied in group formats and as an individual therapy. DBT combines standard cognitive-behavioural techniques, distress tolerance and interpersonal effectiveness. Mindfulness is typically taught and cultivated within DBT.
Fronto-insular cortex	The fronto-insular cortex comprises the ventrolateral prefrontal cortex and the anterior insula. The fronto-insular cortex is thought to form a network with the anterior cingulate cortex that is activated during cognitive challenging tasks. The network is thought to support shifts in activation of different networks, thereby facilitating responses to cognitively challenging events.
Gyrus/gyri	A gyrus is part of the cerebral cortex, collectively known as gyri. Gyri that have been discussed within this review include: the middle frontal gyrus, inferior frontal gyrus, middle temporal gyrus, precentral gyrus and postcentral gyrus. The middle frontal gyrus has been implicated in executive function. The inferior frontal gyrus is located within the frontal lobe and is particularly implicated in inhibitory control and risk-taking. The function of the middle temporal gyrus is not yet clear; however, it has been associated with a range of processes including the judgement of distance, facial recognition and access to word meanings whilst reading. The precentral gyrus is predominantly involved in motor control. The postcentral gyrus lies within the parietal lobe and encompasses the primary somatosensory cortex that is involved in the processing of tactile stimuli.
Hippocampus	The hippocampus belongs to the limbic system and is involved in memory and spatial navigation. The hippocampus is also thought to work in conjunction with the prefrontal cortex to down-regulate emotion regulation processes, such as extinction. The hippocampus is also believed to form a network with the posterior cingulate cortex and temporo-parietal junction that is involved in self-projection processes in which autobiographical information influences the processing of other perspectives.
Insula	The insulae have been implicated within diverse functions including homeostasis, perception, cognitive/attentional control, motor control and more recently, interoceptive awareness.

Integrated Body-Mind Training (IBMT; Tang et al., 2009, 2010)	IBMT is a form of mental training that ranges from 3 hours to 5 days. IBMT derives from traditional Chinese treatment approaches and incorporates aspects of focused attention meditation. Additional components include guided imagery and music therapy.
Kundalini yoga	The purpose of Kundalini yoga is to develop mental and physical strength, awareness and character. The practice involves physical poses and an awareness of the breath.
Lentiform nucleus	The lentiform nucleus is a component of the basal ganglia and is involved in sensory and motor functions.
Loving-kindness/mettā meditation	Loving kindness/mettā meditation derives from the Theravadā Buddhist tradition that emphasises loving-kindness towards the self. Practitioners progressively practice the cultivation of loving-kindness towards others.
Mindfulness-based cognitive therapy (MBCT; Segal, Williams, & Teasdale, 2002)	MBCT is a skills-training group programme of a duration of 8-10 weeks. MBCT combines elements of mindfulness and cognitive therapy and was originally designed to treat individuals in remission from recurrent major depression. MBCT is used in the treatment of other psychological difficulties, including anxiety. Components include psycho-education, cognitive restructuring and mindfulness practices.
Mindfulness-based stress reduction (MBSR; Kabat-Zinn, 1990)	MBSR describes a trans-diagnostic programme to reduce psychological distress and improve psychological well-being by developing mindfulness skills. MBSR is a group programme of 8 weeks duration and consists of 2.5 hours/week classes, home practice and a single whole-day class. Typical components include sitting and walking mindfulness and yoga.
Parietal lobe	The parietal lobe integrates sensory information from a range of modalities and is involved in spatial awareness and navigation.
Posterior cingulate cortex (PCC)	The PCC forms part of the default mode network and has been implicated in self-awareness, pain experience and episodic memory retrieval. The PCC, temporo-parietal junction and hippocampus are also hypothesised to form a network implicated in self-projection processes and the organisation of self-referential stimuli within autobiographical memory.
Precuneus	The precuneus is part of the default mode network and is engaged during stimulus significance appraisals. It is sometimes implicated in self-referential processing.

Prefrontal cortex (PFC; including lateral/dorsolateral PFC, ventral PFC, medial/dorsomedial PFC)	The prefrontal cortex is located within the frontal lobes. The PFC predominantly represents higher-order function and is implicated in planning, decision making, behaviour regulation and personality expression. The PFC can be subdivided into anatomical regions. The lateral PFC is involved in broad executive control and dysfunction within this area has been associated with threat processing. Dorsolateral regions are thought to be involved with on-line information processing and the highest-order functions of the PFC. The dorsolateral PFC has also been implicated in attention and processes such as cognitive reappraisal and meta-cognitive awareness. Ventral areas are particularly involved in impulse control and the regulation and maintenance of ongoing behaviour. Medial regions are also involved in emotion regulation, social behaviour and self-referential processes. The dorsomedial PFC is particularly involved in decision-making, the detection of internal responses, conflicts and attentional processes.
Putamen	The putamen is a dopaminergic structure that is part of the basal ganglia implicated in learning, motor control, cognitive flexibility and attentional control.
Somatosensory cortices (including primary somatosensory neocortex and secondary somatosensory cortex)	The primary somatosensory neocortex lies across the central sulcus and behind the primary motor cortex. The secondary somatosensory cortex lies on the parietal operculum. Both regions are involved in the processing of sensory stimuli.
Spiritual meditation	This term encompasses practices characterised by the focus of attention on a religious/spiritual meditative phrase or mantra.
Sulcus (including superior frontal sulcus and intraparietal sulcus)	A sulcus is a fissure within the brain that surrounds gyri. The superior frontal sulcus lies between the superior frontal gyrus and the middle frontal gyrus. The intraparietal sulcus lies on the parietal lobe. Both sulci have been associated with orienting capabilities.
Temporo-parietal junction	The temporo-parietal junction is a region where the temporal and parietal lobes join. It is implicated within self-distinction processes and exteroceptive awareness.
Transcendental meditation (TM)	TM is a form of mantra meditation that usually involves meditating to a sound or mantra whilst sitting. Whilst TM has sometimes been considered to be a form of focused attention, this is contentious and others have suggested that it is conceptually different since qualities of mindfulness are not emphasised within this practice.

Vipassanā meditation	This form of meditation is one of the oldest and encompasses various diverse styles and practices with shared components. Sometimes referred to as “insight meditation”, it includes elements of both focused attention and open monitoring meditation practice in the development of a mindful awareness.
Visual cortex	The visual cortex is located in the occipital lobe and is involved in the processing of visual information.
Zen meditation	This form of meditation is one of the oldest and encompasses various diverse styles and practices with shared components. Zen meditation involves the practice of focused attention and open monitoring techniques.