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

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ABSTRACT

Mindfulness meditation techniques are increasingly popular both as a life-style choice and therapeutic adjunct for a range of mental and physical health conditions. However, little is known about the mechanisms through which mindfulness meditation and its constituent practices might produce positive change in cognition and emotion. Our study directly compared the effects of Focused Attention (FA) and Open-Monitoring (OM) meditation on alerting, orienting and executive attention network function in healthy individuals. Participants were randomized to three intervention groups: open-focused meditation, focused attention, and relaxation control. Participants completed an emotional variant of the Attention Network Test (ANT) at baseline and post-intervention. OM and FA practice improved executive attention, with no change observed in the relaxation control group. Improvements in executive attention occurred in the absence of change in subjective/self-report mood and cognitive function. Baseline levels of dispositional/trait mindfulness were positively correlated with executive control in the ANT at baseline. Our results suggest that mindfulness meditation might usefully target deficits in executive attention that characterise mood and anxiety disorders.

1. Introduction

Mindfulness meditation refers to a combination of techniques that encourage practitioners to pay attention 'on purpose, in the present moment and non-judgementally' (Kabat-Zinn, 1990, see recent debate in Williams and Kabat-Zinn, 2011) and to foster broad improvements in thinking (cognition) and emotional well-being.

Clinical interventions that employ mindfulness techniques, such as Mindfulness-based Stress Reduction (MBSR; Kabat-Zinn, 1990) and Mindfulness-based Cognitive Therapy (MBCT; Segal et al., 2002) have been shown to be beneficial in major depression (e.g. relapse prevention, Ma and Teasdale, 2004), attention deficit hyperactivity disorder (Zylowska et al., 2008), generalized anxiety disorder (Evans et al., 2008), and some physical health conditions e.g. chronic pain (see meta-analysis by Grossman et al., 2004). Though mindfulness/meditation-based interventions offer promise for a range of physical and neuropsychiatric conditions, a better understanding of the neuropsychological 'mechanisms of action' in meditation/mindfulness based interventions is required to (i) further optimise treatment protocols for clinical populations and (ii) better inform a growing population of individuals who choose to incorporate regular practice into daily-life (see Holzel et al., 2011; Rubia, 2009).

Recent component-process models of mindfulness meditation propose 'attention regulation' as one key mechanism through which mindfulness effects change (Holzel et al., 2011). Neurocognitive models of meditation place specific emphasis on two distinct attentional processes; focused attention and open-monitoring (Lutz et al., 2008; Manna et al., 2010). Focused attention (FA) involves maintaining sustained selective attention towards a volitionally chosen object (e.g. localised sensation of breathing) and engaging in 'self-monitoring' for intrusive thoughts and attentional distractors. In contrast, open-monitoring (OM) involves no deliberate de-selection of stimuli, but active monitoring and acceptance of internal and external sensation to promote a receptive field of non-judgemental awareness. By encouraging an attentional focus towards internal emotional experiences (yet recognising them as subjective and prone to personal bias), OM attention mechanisms relate to both attentional and affective/attitudinal mindfulness facets, in contrast to FA which exploits exclusively attentional skills.

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

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

Growing evidence from cognitive-behavioural paradigms suggests mindfulness meditation can modulate various aspects of cognition including attention stability during dichotic listening (Lutz et al., 2009), cognitive capacity in attentional blink paradigms (Slagter et al., 2007), and working memory (Chambers et al., 2008; Van Vugt and Jha, 2011) – see Chiesa et al. (2011) for recent systematic review of 23 studies.

This work complements efforts in neuroimaging: individuals receiving a 6-week course of mindfulness training (MT) demonstrated increased dorsolateral prefrontal responses alongside improvements in cognitive inhibition (Allen et al., 2012), and recipients of an intensive 3-month retreat showed reduced EEG variability alongside attentional improvements (Lutz et al., 2009) in line with mathematical modelling approaches that have demonstrated reduced RT variability after an intensive 1-month MT retreat. Additionally, fMRI correlates of novice meditators during a focused breathing task demonstrated increased activity in fronto-parietal regions associated with attention control compared to controls in a 'mind-wandering' condition (Dickenson et al., 2013). Recent findings also indicate that mindfulness may increase attentional efficiency: an 8-week MBSR course caused decreased recruitment of the dorsomedial prefrontal cortex during interoceptive attention (Farb et al., 2013).

Whilst observations of increased attentional stability and prefrontal inhibition would support predicted increases in executive attention over better alerting/orienting, to date findings regarding the effects of mindfulness meditation on attention network function are mixed. Experienced mindfulness meditators (compared to novices) can demonstrate increased orienting function (Van den Hurk et al., 2010), executive control (Jha et al., 2007; Van den Hurk et al., 2010) and alerting function after an additional month of intensive practice (Jha et al., 2007). Similarly studies in naïve/novice participants have shown that 8 weeks of MBSR practice leads to improvement in orienting function (Jha et al., 2007), whilst short integrative body-mind interventions (IBMT) comprising 5×20-min sessions over 1 week improve executive attention (Tang et al., 2007) with two 15-min focused-breathing mindfulness sessions shown to improve alerting function (Polak, 2009). Previous mixed results may reflect differences in the mindfulness-meditation practices used across studies (i.e. the extent to which they emphasise FA (e.g. Polak, 2009) or OM (e.g. Tang et al., 2007) alongside varying elements of acceptance, self-compassion etc.), and further argue the need to better understand the role of component meditation processes in modulating cognition and emotion processing (Lutz et al., 2008).

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

Evidence using the ANT suggests that executive control may be disrupted by negative task-irrelevant stimuli (see Finucane, 2011; Finucane and Power, 2010; O'Toole et al., 2011) although studies using task-relevant emotional cues have not demonstrated this (Cohen et al., 2011). Furthermore, Cohen et al. (2011) suggest that increased demand on limited attentional resources moderates the effect of emotion on attentional functioning. Evidence from other paradigms (e.g. visual-probe, Stroop task) suggests that selective attention to emotional stimuli is particularly characterised by a bias in the initial *orienting* of attention to emotional cues (see Bar-Haim et al., 2007, for a review).

We predicted that FA and OM mindfulness practice would increase executive control (but not alerting/orienting) from baseline to follow-up compared to a relaxation control group (which would show no change). We predicted greater improvement following focused attention given its emphasis on attentional acuity and efficient disengagement from distractor stimuli (such as flankers in the ANT). Furthermore consistent with cognitive models of threat-processing we predicted that our novel emotional ANT would reveal an effect of stimulus valence on orienting network function consistent with spatial hypervigilance to threat, and for this effect to increase following meditation (see Van den Hurk et al., 2010; Jha et al., 2007) and particularly after OM given its cultivation of greater receptive awareness to in-situ information.

2. Method

2.1. Participants

Ten male and 66 female young adults ($M=20.3$ years; S.D.$=4.1$) with no prior formal experience of mindfulness meditation were recruited through advertisements placed around the University of Southampton. Participants received course credit or money in return for participation. Participants were randomly allocated to one of three experimental groups: Focused Attention Meditation ($N=24$), Open Monitoring Meditation ($N=25$), and test–retest control ($N=27$). One-way ANOVA confirmed that groups did not differ significantly in age, $F_{(2,73)},=0.47$, $p=0.63$ or gender, $\chi^2=1.61$, $p=0.45$. Box-plots across the entire sample indicated that three participants in the control group were outliers on self-report generalized trait anxiety (STAI). To ensure that groups did not significantly differ in baseline levels of trait anxiety these participants were subsequently removed from the study. Thus data is reported from 73 participants: FA group, $n=24$, OM group, $n=25$; control group, $n=24$. Groups did not differ significantly in age, $F_{(2,70)},=0.40$, $p=0.67$ or gender, $\chi^2=1.45$, $p=0.48$.

2.2. Materials and procedure

Participants attended pre- and post-intervention test sessions during which they completed a modified attention network test (details below) and established standardized questionnaire measures of state and trait anxiety (STAI, Spielberger et al., 1983), attention control (Attention Control Scale, Derryberry and Reed, 2001) and trait mindfulness (Mindful Attention Awareness Scale, MAAS; Brown and Ryan, 2003). The study received approval from University of Southampton research ethics and research governance committees.