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# Internal and external attention and the default mode network

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ABSTRACT

Focused attention meditations have been shown to improve psychological health and wellbeing and are nowadays an integral part of many psychotherapies. While research on the neural correlates of focused attention meditation is increasing, findings vary on whether meditations are associated with high or low activity in the default mode network (DMN). To clarify the relationship between focused attention meditation and the activity in DMN regions, it may be helpful to distinguish internal and external attention as well as different phases within one meditation: During focused attention meditation, the practitioner switches between mindful attention, mind-wandering and refocusing. Here, we employed a thought-probe paradigm to study the neural correlates of these different phases. Twenty healthy, meditation naïve participants were introduced to external (mindfulness of sound) and internal (mindfulness of breathing) attention meditation and then practiced the meditation at home for four consecutive days. They then performed the same focused attention meditations during fMRI scanning, in four runs alternating between internal and external attention. At pseudorandom intervals, participants were asked whether they had just been focused on the task (mindful attention) or had been distracted (mind-wandering). During mindful attention, brain regions typically associated with the DMN, such as the medial prefrontal cortex, posterior cingulate cortex and left temporoparietal junction showed significantly less neural activation compared to mind-wandering phases. Reduced activity of the DMN was found during both external and internal attention, with stronger deactivation in the posterior cingulate cortex during internal attention compared to external attention. Moreover, refocusing after mind-wandering was associated with activity in the left inferior frontal gyrus. Our results support the theory that mindful attention is associated with reduced DMN activity compared to mind-wandering, independent of the practitioner's attention focus (i.e., internal vs. external).

## Introduction

Mindfulness is a popular current topic in psychology research and applied clinical psychology alike. Defined as paying attention to the present moment without judgment (Kabat-Zinn, 1994), mindfulness has become an integral part of several modern psychotherapies, such as *Acceptance and Commitment Therapy* (Hayes et al., 2006; Hayes et al., 1999), *Dialectical Behavioral Therapy* (Linehan et al., 2007; Soler et al., 2012) and *Mindfulness Based Cognitive Therapy* (Sachse et al., 2011; Williams and Swales, 2004). Several patient groups experience difficulties with mindfulness in everyday life or during mindfulness meditation (Fossati et al., 2012; Scheibner et al., 2016; Smalley et al., 2009), and for many patient groups, mindfulness meditation is an effective treatment strategy (Baer, 2015; Williams, 2008). In healthy populations, mindfulness meditation has been shown to reduce stress and improve mental and physical wellbeing (Chiesa and Serretti, 2011; Farb et al., 2015; Grossman et al., 2004). However, while over two hundred studies on the effects of mindfulness meditation exist (Grossman et al., 2004; Ivanovski and Malhi, 2007; Khoury et al., 2013), the neural correlates of mindfulness meditations have not been extensively studied (Baron Short et al., 2010; Brefczynski-Lewis et al., 2007; Brewer et al., 2011; Dickenson et al., 2013; Farb et al., 2015; Hasenkamp et al., 2012; Hölzel et al., 2007). Different types of mindfulness meditations exist and, in particular, focused attention meditation and open monitoring meditation have been distinguished in the literature (Lutz et al., 2008) and may have distinct neural correlates (Fox et al., 2016). During focused attention meditation, practitioners mindfully focus on one object of attention, while during open monitoring exercises, practitioners are mindfully

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aware of any present moment experience. In the current study, we investigated the neural correlates of focused attention meditation, which we here refer to as "internal attention meditation" (i.e., mindfulness of breathing) or "external attention meditation" (i.e., mindfulness of sound), depending on the focus of attention. In particular, this study aimed to clarify the relationship between internal and external attention meditation and a neural network called the default mode network.

The default mode network (DMN) consists of a set of brain regions that were observed to consistently deactivate from baseline during a wide variety of tasks (Raichle et al., 2001). The regions that are most commonly associated with the DMN are the medial prefrontal cortex (mPFC), the posterior cingulate cortex (PCC), the precuneus, the temporoparietal junction (TPJ), the posterior inferior parietal lobule, and the hippocampus. Understanding the role of the DMN has been described as one of the most fascinating challenges of modern neuroscience (Raichle, 2010) and different theories have been put forward. On the one hand, some researchers argue that the DMN may represent the neural correlate of mental processes requiring internal attention and that the DMN is deactivated whenever individuals are attending to external events (Buckner et al., 2008; Golland et al., 2007; Greicius and Menon, 2004; Raichle, 2010; Vanhaudenhuyse et al., 2011). According to this theory, meditation should activate the DMN if subjects practice internal attention meditation compared to external attention meditation. On the other hand, some researchers argue that internal and external attention entail a variety of cognitive states that are not always antagonistic (Dixon et al., 2014). Instead, DMN activity may be correlated with mind-wandering as opposed to processes involving focused attention (Christoff et al., 2009; Mason et al., 2007). Mind-wandering is here defined as off-task thinking such as memory retrieval, planning for the future, or judging the present. According to this theory, both internal and external attention meditation should deactivate the DMN relative to mind-wandering (Mrazek et al., 2012).

To date, empirical evidence that would support high or low DMN activity during meditation are inconclusive. Hölzel et al. (2007) demonstrated that a mixed group of experienced meditators and beginners showed higher activity levels in the left precuneus and mPFC during an internal attention meditation compared to an arithmetic task. In addition, experienced meditators showed more activity in the mPFC than beginners in the same contrast. In contrast, Brewer et al. (2011) found that expert meditators showed less activity in the mPFC, PCC and the precuneus than beginners during three different mindfulness meditations and Farb et al. (2013) showed that meditation training predicted decreased recruitment of the dorsomedial prefrontal cortex (dmPFC) during internal attention meditation compared to two visual tasks. Herwig et al. (2010) found that meditation beginners showed mPFC and amygdala deactivations as well as increased activation in somatosensory areas during a mindful focus inducing "feel" condition compared to a self-reflection inducing "think" condition. Dickenson et al. (2013) found stronger activations in the dmPFC, the hippocampus and the left TPJ during internal attention meditation compared to unfocused attention in beginners; yet, other areas of the DMN, such as the precuneus and the PCC, were less activated in the mindful compared to the control task. Hasenkamp et al. (2012) found that meditators with intermediate experience showed an association between self-reported phases of mind-wandering during an internal attention meditation and activity in areas of the DMN, but also more activity in the posterior insula and mid-cingulate. Awareness of mind-wandering was associated with increased activity in the anterior cingulate cortext (ACC) and anterior insula, mindful attention was associated with increased activity in the right dorsolateral prefrontal cortex (dlPFC), and refocusing was associated with activations in the right inferior frontal gyrus and lateral PFC (lPFC), posterior parietal cortex as well as the thalamus.

There could be at least two explanations for discrepancies in previous findings regarding the relationship of focused attention meditation and the DMN. First, if the DMN is associated with mind-wandering (Christoff et al., 2009; Mason et al., 2007; Mrazek et al., 2012), the observed level of DMN activity in previous studies may reflect the frequency of mind-wandering in the study samples and in the employed meditation tasks. In a typical focused attention meditation, practitioners mindfully rest their attention on one experience in the present moment. Failure to maintain mindful attention, however, is not uncommon. On the contrary, it is an essential part of any mindfulness meditation: Practitioners are instructed that eventually, their mind may wander off and they may find themselves lost in thought, mind-wandering. As soon as practitioners notice that they are mind-wandering, they should let go of the thought and regain mindful attention. Given the potentially opposite effects of mindful attention and mind-wandering on the DMN (Christoff et al., 2009; Mason et al., 2007; Mrazek et al., 2012), it appears desirable to analyze the above-mentioned phases separately. Second, if the DMN is associated with internal attention (Buckner et al., 2008; Golland et al., 2007; Greicius and Menon, 2004; Raichle, 2010; Vanhaudenhuyse et al., 2011), DMN activity may be influenced by where participants' attention is directed. While most previous studies have investigated neural correlates of internal attention meditation, e.g. mindfulness of breathing, attention can also be directed externally, e.g. mindfulness of sound.

To address the above-raised issues, internal and external attention meditation as well as different phases within a focused attention meditation were distinguished in this study. We employed a thought-probe paradigm (Csikszentmihalyi et al., 1977; Frewen et al., 2008; Frewen et al., 2011; Frewen et al., 2014; Hurlburt, 1980; Scheibner et al., 2016): participants were interrupted at random time intervals during their meditation and asked whether they had just been mindful or mind-wandering. The paradigm used in the present study is similar to a sustained attention to response (SART) task with thought probes, which has been used repeatedly to collect samples of mind-wandering during sustained attention (Christoff et al., 2009; Jha et al., 2016), except that during the SART task, participants do not meditate but perform a visual attention task. In our paradigm, participants were instructed to be mindful of their breathing (internal attention) in half of the trials; in the other half, participants were instructed to be mindful of a sound (external attention). Based on the described theories about the role of the DMN, we derived two opposing hypotheses: If the DMN was associated with mind-wandering on the one hand, all mindful attention compared to mind-wandering trials should be associated with reduced activity in the DMN (hypothesis 1A). If the DMN was associated with internal attention on the other hand, then only external attention would be associated with reduced activity in the DMN compared to mind-wandering; internal mindful attention and mind-wandering would be associated with similar activity levels in the DMN (hypothesis 1B). In addition, we hypothesized that compared to mind-wandering, internal and external mindful attention would be associated with activity in areas typically reported in block design focused attention meditation studies, such as the insula, dlPFC and the ACC (hypothesis 2) (Brefczynski-Lewis et al., 2007; Dickenson et al., 2013). Last, in order to study the neural correlates of refocusing, we investigated the neural activations at the time after participants were interrupted. We assumed that after reported mind-wandering, participants engage in refocusing, while after mindful attention, participants need to refocus to a lesser extent. Therefore, we contrasted these two conditions. We hypothesized that after mind-wandering, participants show more neural activity in areas that are typically associated with attention shifting, such as the lPFC and thalamus (Hasenkamp et al., 2012; Wang et al., 2014) compared to the same time period after mindful attention (hypothesis 3).