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How similar are the changes in neural activity resulting from mindfulness practice in contrast to spiritual practice?

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ABSTRACT

Meditation and spiritual practices are conceptually similar, eliciting similar subjective experiences, and both appear to provide similar benefits to the practicing individuals. However, no research has examined whether the mechanism of action leading to the beneficial effects is similar in both practices. This review examines the neuroimaging research that has focused on groups of meditating individuals, groups who engage in religious/spiritual practices, and research that has examined groups who perform both practices together, in an attempt to assess whether this may be the case. Differences in the balance of activity between the parietal and prefrontal cortical activation were found between the three groups. A relative prefrontal increase was reflective of mindfulness, which related to decreased anxiety and improved well-being. A relative decrease in activation of the parietal cortex, specifically the inferior parietal cortex, appears to be reflective of spiritual belief, whether within the context of meditation or not. Because mindful and spiritual practices differ in focus regarding the 'self' or 'other' (higher being), these observations about neurological components that reflect spirituality may continue work towards understanding how the definition of 'self' and 'other' is represented in the brain, and how this may be reflected in behaviour. Future research can begin to use cohorts of participants in mindfulness studies which are controlled for using the variable of spirituality to explicitly examine how functional and structural similarities and differences may arise.

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1. Introduction

Individuals who practice religiously and/or spiritually (R/S), and also those who practice mindfulness meditation, report a greater sense of compassion, wellbeing, feeling of wholeness, decreased anxiety, and faster recovery from mental illness (Cohen, Jimenez, & Mittal, 2010; Giovagnoli, da Silva, Federico, & Cornelio, 2009; Ivanovski & Malhi, 2007; Sasaki, Kim, & Xu, 2011; Shapiro & Walsh, 2003). Research has suggested that the processes trained by mindfulness meditation involve attention regulation, body awareness, emotional regulation (reappraisal, exposure, extinction, and reconsolidating), and perspective of the self (Hölzel et al., 2011a, 2011b). In this review, mindfulness meditation will be defined as 'an expansion of attention in a non-judgemental and nonreactive manner, in order to become more aware of one's current sensory, mental and emotional experience' (Ivanovski & Malhi, 2007). In contrast to mindfulness meditation, spiritual practice can be broadly defined as focusing on an internal and external sense of connection to a higher entity, or embodiment, such as Mother Nature. Almost every culture contains traditions of spiritual practice in one form or another. As spiritual practice is so widespread in human culture, everyone has a common understanding of the phenomenon, regardless of whether they practice R/S or not. However for the purposes of this paper; we will define spiritual practice as focusing on spiritual transcendence and connection with a higher entity(s), with methods such as prayer or spiritual meditation.

An aim of both mindfulness practice and spiritual practice is the enhancement of the subjective experience of the mind by focusing on positive emotion, which can result in an increased sense of social support, purpose in life, and a decrease in illness symptoms (Fredrickson, Cohn, Coffey, Pek, & Finkel, 2008). Evidence has also shown that spiritual practice directly improves emotional experience through an increased sense of meaning and hope, and alleviating feelings of fear and loneliness (Clark, Drain, & Malone, 2003). Similarly, mindfulness practice has shown to lead to a receptive and attentive attitude to self-attribution of emotion, increased coping strategies and greater wellbeing, as well as instilling compassion for the self and empathy for others (Weinstein, Brown, & Ryan, 2009). Both mindfulness and spiritual practice often approach enhancing the subjective experience of the mind in a similar manner, such as focusing on present moment experiences (e.g. through prayer or meditation), seeking transcendence (the process of developing higher consciousness), and fostering acceptance and monitoring of emotional responses. Further, research has demonstrated, through structural equation modelling, that daily spiritual practice enhances the practice of mindfulness towards psychological health benefits (Greeson et al., 2011).

Since both mindfulness meditation and spiritual practice display similar outcomes, both employ comparable methods, and have been shown through self-report measures to have a relationship (Greeson et al., 2011), we feel it is valuable to analyse what the similarities and differences are in terms of neural activation patterns and changes to neural structure resulting from each type of practice. Answering this question could further inform our understanding into the role that spirituality plays in illness recovery, and how much the attributes of R/S may contribute to the positive effects of mindfulness practice. It may also inform future research to what degree R/S may confound results that use mindfulness participants from different belief frameworks. If the role of R/S in mindfulness meditation is a beneficial variable, this information may further inform clinical research and practice.

Meditation is broadly used to describe attention training practices that observe and regulate the mind and the body (Cahn & Polich, 2006). These practices are often divided into concentrative practices, such as Transcendental Meditation (TM) and 'open-monitoring' or mindfulness practices. Concentrative meditation often involves a single point of focus, and often considered a more 'zoom-lens' attentional mechanism, often concentrated on a single point in the body (Valentine & Sweet, 1999) or a mantra, in the case of TM. Mindfulness meditation on the other hand has been used in recent years in medicine and healthcare to describe the practice of attentional focal non-reactivity to inner experiences, and often viewed as a 'broader spectrum' meditation, which encourages the free flow of any thought that may pass through consciousness, with no specific extra attention paid to any particular thought (Sayadaw, 1972). There are a range of traditional meditation practices and traditions that emphasise mindfulness, such as Zen and Vipassana (insight) meditation, and these are based upon traditional practices, such as used in Buddhist culture. There are also a number of modern psychological therapies that include mindfulness as a central component, including mindfulness based stress reduction (MBSR), mindfulness-integrated cognitive behaviour therapy (MiCBT), acceptance and commitment therapy (ACT) and mindfulness based cognitive therapy (MBCT) (Ivanovski & Malhi, 2007). These therapies have proven effective in treating generalised anxiety disorder, obsessive compulsive disorder, substance abused, psychosis, relationship conflict, as well as preventing relapse of major depressive disorder (Williams, Teasdale, Segal, & Soulsby, 2000).

For the purposes of this review, the most important difference between spiritual practice and secular mindfulness meditation, is that spiritual practice involves focusing on the connection to, and presence of, a higher being or embodiment; God or otherwise (Coakley, 2013). In contrast, secular mindfulness practice is primarily an external and internal attentional strategy, and although the traditional practices can produce transcendental experiences and the feeling of unity with a higher being, secular and modern mindfulness practices do not necessarily emphasise this aspect (Johnstone, Bodling, Cohen, Christ, & Wegrzyn 2012; Newberg & d'Aquila, 1998). Mindfulness has been used in healthcare and medical practice in a decontextualized setting, which emphasises its attentional and cognitive benefits rather than aspects of spiritual practice (Berkovich-Ohana, Dor-Ziderman, Glicksohn, & Goldstein, 2013). As such, the connection to a higher being (or lack of) is the variable that contrasts between the two groups.

Both mindfulness and spiritual practices have been researched with neuroscientific techniques individually. However, only three direct comparisons of both of R/S and mindfulness practice have been conducted, and none of these have examined the constructs from a neurological perspective (Carmody, Reed, Kristeller, & Merriam, 2008; Leigh, Bowen, & Marlatt, 2005; Ying, 2009). Additionally, the interpretation of mindfulness studies is potentially confounded by the fact that mindfulness research often involves cohorts of participants who adhere to a spiritual framework. In order to counteract this potential confound, this review examined studies involving modern clinical and secular versions of mindfulness separately, and comparisons were made across the three different types of groups (R/S, mindfulness practice with a spiritual framework, and mindfulness practice with a secular framework). Using this approach, focus on the neurological underpinnings of the subjective outcomes of both practices enable us to determine the functional similarities and differences in brain changes between individuals who practice mindfulness and individuals who practice religiously or spiritually.

2. Methodology

2.1. Scope of the current review

The purpose of this article is to review research that examines the neurological underpinnings of meditation and R/S practice, and the similarities and differences between the two. It will aim to answer questions about why meditational practice and R/S practice share some similar subjective experiences and potential benefits, and which cortical areas overlap in secular and spiritual meditation, and R/S practice. It will also aim to provide improved understanding to clinical western mindfulness practice into how spirituality may play a neurological variable in mindfulness practice. This review will focus on fMRI, MRI, PET, and EEG techniques, specifically examining the different groupings of secular and spiritual meditation and R/S practice. Previous reviews have examined the neurological changes resulting from mindfulness meditation, but without directly examining spirituality as a variable (Ivanovski & Malhi, 2007; Cahn & Polich, 2006; Hölzel et al., 2011a, 2011b). Spirituality and meditation share similar subjective experiences, and further, neurological meditation research may be potentially confounded by whether participants adhere to a spiritual framework or not. This review will therefore attempt to tease apart three groups within the context of neurophysiological research: spiritual meditators, secular meditators, and individuals who do not meditate but practice spiritually.

2.2. Methods

To be able to fully review the literature on meditation and R/S neurological change, both Google Scholar and PubMed databases were searched. The terms related to neural changes of mindfulness practice were 'cortical changes mindfulness', 'MBCT', 'EEG mindfulness', 'mechanisms of mindfulness', and 'fMRI mindfulness', and search terms related to the neural change of R/S belief were 'subjective spiritual belief', 'EEG spiritual belief', 'mechanisms of spiritual belief', and 'fMRI spirituality'. The Google Scholar search returned 1660 articles, while the PubMed search returned 928 articles. Due to the volume of research, only the most phrase-relevant were used. This was determined by excluding any articles which did not directly address functional or neuro-imaging findings from mindfulness studies. Articles that were cited in previous reviews and studies of meditation and R/S belief were also reviewed to ensure any relevant articles overlooked by the database search were still included. Research that focused on qualitative data without cortical analyses was excluded, so that the focus on the review was specifically on cortical changes associated with each group. Non-English articles were excluded. This produced a total of 96 articles examining cortical change within meditation and R/S practice.

3. The neurophenomenological effects of spiritual/religious practice

The links between spiritual practice and positive outcomes have been a focal point of philosophy and literature for millennia, from Hippocrates to Dostoyevsky (Devinsky, 2003). Similarly, early 20th century psychologists, such as Freud and Jung had their own interpretations as to how religion and spirituality play a role into our psyche (Jung, 1966; Palmer, 2003; Tacey, 1997). However, it is only recently that neurophysiological research into spiritual practice has been seen as a valid academic pursuit (McNamara, Sosis, & Wildman, 2011). This research has examined the anecdotal claims that those who are religious or spiritual in clinical populations often develop better coping strategies, leading to a reduction of symptoms (Cohen et al., 2010; Bormann, Liu, Thorp, & Lang, 2012). This happens via biological factors such as decreased cortisol levels (Creswell et al., 2005), higher parasympathetic activity and improved immune response (Seeman, Dubin & Seeman; 2003). Similarly, spiritual practice has been shown to provide a path that can lead to a healthier framework for life (Seybold, 2007; Greeson et al., 2011). For example religious practices have been demonstrated to increase cognitive performance, regardless of the faith orientation of the individual (McCullough & Willoughby, 2009). Spiritual practices have also been shown to provide increased capacity for self-control, resulting in spiritual individuals being better able to limit their use of tobacco (McCullough & Willoughby, 2009).

3.1. Functional neurological changes resulting from R/S

More recently, brain imaging techniques have been able to elucidate the neural changes that take place as a result of R/S practice, and how R/S practices may lead, in some domains, to an increase in healthy lifestyle behaviours. Electroencephalogram (EEG) has been fruitful in highlighting the differences in brain rhythms between non-spiritual and R/S populations. Tenke et al. (2013) found that populations who held R/S beliefs over a 10-year period demonstrated increased medial posterior alpha power (both low and high sub-bands) and higher resting alpha power at a single time point. Increases in the alpha rhythm have been shown to indicate a decrease or suppression in cortical activity (Goldman, Stern, Engel, & Cohen, 2002) and the function of increased alpha has been suggested to be improved neural efficiency through the inhibition of brain regions not required for a task (Bazanova & Vernon, 2014). Increased alpha power in R/S populations was found to correlate with a decreased risk of developing major depression in individuals who had immediate family member with the disorder (a known risk factor developing depression) (Miller et al., 2014). The decreased risk of developing major depressive disorder was correlated with how important R/S was to the individual (measured via self-reports), with a stronger correlation with amount of actual daily practice focused on spirituality and transcendence, rather than with practices like church attendance (Kelley & Miller, 2007).

3.2. Structural neurological changes resulting from R/S

In addition to the studies of neural activity with EEG, structural changes have been found with MRI. Miller et al. (2014) used a longitudinal design using magnetic resonance imaging (MRI) to examine brain volumes of 103 adults who were at high or low risk for developing depression, and found self-attributed importance of religiousness or spirituality (regardless of the denomination of worship) to be associated with an increased grey matter in the left and right parietal regions of the cortex, as well as thickening in the occipital region, right mescal frontal, and left cuneus and precuneus regions. This neurophysiological change was correlated strongly with the high-risk group, with thicker cortical regions demonstrating a buffer for the development of depressive symptoms. In general, the research using EEG and MRI appears to indicate adaptive inhibition and strengthening of the parietal cortex in R/S groups. This may reflect increased parietal functioning and indicate that the parietal lobe plays a role in the belief of R/S, or that R/S subjective belief affects parietal neuroplasticity to alter selective brain function and inhibition.

In addition to the EEG and MRI research, functional magnetic resonance imaging (fMRI) research examining R/S has identified a partial right hemisphere bias in brain areas responsible for increased religiosity (McNamara & Butler, 2013). The authors found that activity in the right temporal lobe, right dorsolateral prefrontal cortex, dorsomedial, orbitofrontal, limbic system, and basal ganglia are all crucial nodes in the neural orchestration of religiosity. Research has also supported the idea that spiritual transcendence, decreased narcissism and perceived connection to a higher being is associated with increased frontal lobe activity and decreased right parietal lobe activity (Johnstone et al., 2012).

Other research has similarly implicated the role of the parietal lobe in experiences of spiritual transcendence, with gliomal and meningiomal damage to the parietal area causing individuals to express an increased feeling of spiritual transcendence (Urgesi, Aglioti, Skrap, & Fabbro, 2010). This was found in contrast to anterior lesions, which decreased the experience of spiritual transcendence in individuals. These results can either be interpreted to demonstrate an isolated importance of the parietal lobe or frontal lobe, or the importance of the fronto-parietal network in the experience of R/S, perhaps with an increased ratio of frontal to parietal function leading to increased R/S experience. Evidence seems to support that the balance of inhibited parietal activity and amplified prefrontal activity may lead to the strengthening of R/S experience.

McNamara and Butler (2013) concluded that this decrease in the activity of the fronto-parietal network, along with increases in the activity of the fronto-temporal network, is the basis of heightened religious and self-transcendental experiences. The evidence suggests a right bias in fronto-temporal damage leads to decreased R/S experience, which can match with research showing bilateral posterior ablation increased R/S experience, as they are connected but explicitly different regions. Research in the future would profit from examining the effect of left and right posterior lesions on R/S separately to determine whether both hemispheres contribute to R/S equally, or whether one hemisphere is more responsible for R/S experience.

Clues to answering this question may be found in research using anaesthetic disruption to each parietal lobe independently. This research has compared the effect of disruptions to each hemisphere separately on performance in the 'self-other task', which involved patients being anaesthetised either in the left or right hemisphere while being asked to remember a face on screen which was an amalgamation of the patients face with that of a famous individuals face. The forced choice between a picture of the patient's own face, and that of a celebrity face, was then required. When the left hemisphere was anaesthetised, all participants chose their own face in the task, however when the right hemisphere was disrupted, nearly all participants selected the famous individuals face as the one they had seen (Keenan, Nelson, O'Connor, & Pascual-Leone, 2001). The authors suggest that this indicates the right hemisphere is responsible for self-awareness and higher consciousness.

The identification of the 'Self' and 'Other' has been further examined with regards to the role of the parietal lobe (along with the prefrontal cortex and insula) through electrophysiological and neuroimaging research in monkeys and humans (Blakemore & Frith, 2003; Jackson & Decety, 2004; Rizzolatti & Craighero, 2004). Research involving disruption of these areas by anaesthetic, lesion and transcranial magnetic stimulation (TMS) has been found to lead to disorders of the self, and difficulties in identifying with the self and others (Brozgold et al., 1998; Feinberg & Keenan, 2005; Mesulam, 2000). Alterations in feelings of being connected to a higher power, or belonging to something larger than oneself, are essentially alterations to the sense of self and other. Therefore, taken together, the association between decreased parietal lobe activity and R/S experience, and the disruption of this area leading to decreased performance in identifying self and other suggests that this area is crucial in the ability to take another's perspective and forming an experience of higher unity. As such, we might expect that these changes are specific to individuals who perform spiritual practices, and will not be found in individuals who practice secular mindfulness, and do not focus on a connection with a higher entity, but with a focus on overcoming attachment to the self without spiritual connotation.

A study by Azari et al. (2001) further highlights the changes to the frontal cortex and parietal cortex in R/S individuals. Their research used positron emission tomography (PET) scans to examine neural activity during the reading of a psalm in religious individuals. They found the fronto-parietal circuits of these individuals were shown to display significantly more blood flow when compared to two non-religious activities (the reading of a German children's nursery rhyme and numbers from the Dusseldorf phone book). While an increase in activity in the fronto-parietal circuit may appear to contradict the research conducted with fMRI and EEG, increased cerebral blood flow has been shown to be related to a decrease in alpha magnitude. Indeed, when participants were tested simultaneously with EEG and PET mapping during rest and simple motor tasks (Cook, O'Hara, Uijtdehaage, Mandelkern, & Leuchter, 1998), this relationship was observed. This alpha change has been discussed above as indicating a change in cortical activity (Goldman et al., 2002) via the desynchronisation of the region (Kirschfeld, 2005). Cook et al. (1998) notes that this finding is in line with cerebral perfusion alone. Further research needs to be conducted to definitely define the neurophysiological importance of this. Bazanova and Vernon (2014) however suggest that the data pertaining to the link between cerebral perfusion and cortical activity is too ambiguous and varied to be able to make conclusions at this point in time. This suggests that Azari et al's (2001) results could reflect increased fronto-parietal activity, or at the least change and adaptation of the fronto-parietal circuit during spiritual practice (Kirschfeld, 2005).

It could be suggested from the above research that the posterior lobe therefore is the seat of self-identification, inside the paradigm of 'self' and 'other'. When there is a decrease or loss of posterior function (through a lesion or anaesthetic), the prefrontal lobe may be unable to maintain the processes that give rise to the notion of an inclusive 'self', leading to an increase in the perception of an external agent. The literature seems to suggest a right hemisphere bias to the self-other effects of the posterior lobe. This hypothesis does not necessarily posit presence of a strengthened prefrontal lobe, but merely that the balance of function in the fronto-parietal network is crucial to weakening or strengthening the belief of a higher being.

In conclusion, neurological research into the area of spirituality is relatively sparse (see Table 1). However, spiritual practice and experience seem to be consistently related to a decrease in parietal lobe activity and an increase in frontal lobe activity, and a definite relationship between fronto-parietal communications when an individual has experiences of R/S. The main observations of these studies are that in individuals who partake in more R/S practice and experience, increases in parietal and frontal lobe thickness occur, prefrontal relative function is increased, as well as increased alpha activity over parietal regions. During spiritual practice, blood flow and metabolism increases are found in the fronto-parietal network and decreased cortical activation is found in the parietal region. While results show significant changes, the methods of assessing activity used in each study vary. Further research is therefore required.

4. The neurophenomenological effects of mindfulness meditation

Following the work of Kabat-Zinn and Burney (1981), Kabat-Zinn (1982), the practice of mindfulness meditation has been incorporated widely into clinical practice as a viable, effective, non-pharmacological and non-invasive method to decrease psychological symptoms of anxiety and depression, PTSD, bipolar disorder, relationship distress, psychosis, and alcoholism (Brown & Ryan, 2003; Hofmann et al., 2010; Lang, 2013; Marlatt et al., 2004; Smith et al., 2011; Baer, 2003). Additionally, mindfulness meditation has been shown to increase cognitive attention, working memory, and executive function (Jha, Krompinger, & Baime, 2007; Weick & Sutcliffe, 2006), and improve physiological health by decreasing blood pressure and increasing parasympathetic innervation (Seeman, Dubin, & Seeman, 2003). Perhaps unsurprisingly given the cognitive and mental health benefits associated with mindfulness, EEG, even-related potential (ERP), PET, MRI and fMRI technologies have uncovered a number of short and long term mechanistic neural changes that result from mindfulness meditation (Aftanas & Golocheikine, 2003; Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004). Research efforts are now being made

Table 1
Summary of neural changes as a result of R/S practice.

Author	Neurological method	Participants background	Participant no.	Main findings
Tenke et al. (2013)	EEG (13 Electrodes)	Important vs. Not important spirituality	52	Increased resting alpha levels over P7, P3, P4 and P8 regions in individuals who considered spirituality as 'highly important'
Miller et al. (2014)	MRI	High or low risk for depression concomitant with importance of R/S	103	Increased parietal cortical thickness in high R/S individuals. Especially those at high risk for depression
Johnstone et al. (2012)	fMRI	Neurologically impaired outpatients measured for spiritual belief and daily experience of transcendence	20	Decrease in right parietal lobe activity and increase in frontal lobe activity in R/S individuals during neuropsychological assessment. This scaled with level of R/S belief measured via self-report measures
Azari et al. (2001)	PET scan	6 Religious and 6 non-religious individuals	12	Increased prefrontal function and increased mid-parietal function in religious individuals when Psalm was read.
Urgesi et al. (2010)	MRI, Lesion study	24 patients with high-grade gliomas, 24 with low grade gliomas, 20 with recurrent gliomas, 20 with brain meningiomas	88	Individuals who underwent removal of high-grade and low-grade gliomas specifically and significantly had an increased experience of spiritual transcendence

to uncover how the neurological effects of mindfulness meditation are correlated with subjective experience (Brown & Cordon, 2009; Collard, Avny, & Boniwell, 2008). Mindfulness research has often utilised participants from a traditional background of training, and hence research being reviewed in this article will include both modern and traditional frameworks of mindfulness. Potential confounds of this mix will be discussed.

4.1. fMRI, MRI, and Single Photon Emission Computed Tomography (SPECT)

Similar to studies of individuals who practice R/S, both frontal and prefrontal changes have been demonstrated in individuals who practice mindfulness meditation using fMRI, MRI, and SPECT/PET neuroimaging. Research has mainly indicated an increased engagement of frontal and prefrontal cortices in meditators compared to controls. These areas are implicated in executive control, including functions such as maintaining and directing attention (Kane & Engle, 2002; Mesulam, 1981). These changes are also concomitant with increased subcortical thickness of the right anterior insula, right middle and frontal superior sulci in meditators (Lazar, Kerr, Wasserman, et al., 2005). These areas are associated with sensory-motor processing, suggesting a greater interoceptive perception in individuals who practice mindfulness. Similarly, research has shown increased cortical thickness in the same areas, as well as increases in the thickness of the dorsolateral prefrontal cortex and anterior cingulate cortex (Hölzel et al., 2008).

The fMRI and MRI data aligns with SPECT and PET neuroimaging, which has indicated that mindfulness meditation results in increased frontal lobe blood flow. This points to increased autonomic control in meditators due to improved frontal modulation of subcortical emotional structures such as the amygdala, hypothalamus and limbic nuclei (Newberg et al., 2003). Blood flow increases were also found in the prefrontal cortex, inferior frontal and inferior parietal lobes. A strong inverse correlation between blood flow in the prefrontal cortex and the ipsilateral superior parietal was found. This change may indicate increased activity of the prefrontal lobe, resulting in increased parietal inhibition during mindfulness meditation.

These findings appear to be consistent across different types of mindfulness practices. Newberg, Pourdehnad, Alava, and d'Aquila's (2003) research comprised a SPECT analysis on Franciscan nuns during meditation, and Newberg et al.'s (2001) research showed that in a similar SPECT analysis, proficient Buddhist meditators displayed significant increases to their prefrontal cortex but decreased blood flow in their superior parietal lobe, compared to controls. This research falls into the overlapping category of mindfulness meditation within a spiritual framework. Therefore these neural changes are quite difficult to compartmentalise within either mindfulness-alone or spiritual-alone categories. These neurological changes therefore may be due to a process that happens during 'state' meditation or through the subjective experience of meditation itself.

4.2. EEG

Studies using EEG to examine the neural activity of individuals who practice mindfulness have found increases in theta and delta in the frontal lobe, as well as increased alpha, delta, and beta 1 levels in the posterior lobe while at rest (Ivanovski & Malhi, 2007). Similar results from both spiritually structured and secular meditation practices found that meditators displayed increased frontal lobe theta and increased posterior alpha power during meditation (Aftanas & Golocheikine, 2001; Lagopoulos et al., 2009).

One of the main clinical benefits of mindfulness meditation, such as modern mindfulness-based stress reduction (MBSR), is improved attention, reduced mind-wandering, and as a result, decreased stress (Grossman, Niemann, Schmidt, & Walach, 2004). These reductions have been attributed in part to a shift away from activation of the Default Mode Network (DMN). The DMN includes the medial prefrontal, posterior cingulate and inferior parietal cortices (Brewer et al., 2011; Greicius, Supekar, Menon, & Dougherty, 2009). Activation of the DMN has been associated with rumination, worry, depression and anxiety (Greicius et al., 2007; Hamilton et al., 2011; Zhao et al., 2007). Reduced DMN activity has been found to be potentially as a result of increased frontal midline theta (FMT) activity (Brewer et al., 2011; Ivanovski & Malhi, 2007; Taylor et al., 2012). Frontal midline theta increases have been a focus of research examining mindfulness meditation with EEG (Cahn & Polich, 2006).

Increases in FMT have been suggested to be generated via the anterior cingulate, medial prefrontal or dorsolateral prefrontal cortices (Asada, Fukuda, Tsunoda, Yamaguchi, & Tonoike, 1999; Ishii et al., 1999), and increased frontal midline theta has been suggested to be a result of increased prefrontal function (Ishii et al., 1999). Increased frontal midline theta activation has been shown to be a direct result of mindfulness meditation (Baerentsen, Hartvig, Stodkilde-Jorgensen, & Mammen, 2001; Cahn & Polich, 2006; Farb et al., 2007; Hölzel et al., 2011a, 2011b; Ivanovski & Malhi, 2007; Lazar et al., 2005; Newberg et al., 2001; Newberg et al., 2003).

While increased frontal midline theta has more often been associated with concentrative meditation (Aftanas & Golocheikine, 2002), comparisons between concentrative and mindfulness meditation practices have often shown mindfulness meditation to produce greater significant increase of frontal theta and increased alpha activity in central posterior regions, such as the inferior parietal region (Dunn, Hartigan, & Mikulas, 1999). This dual process of inhibition in posterior regions and increased activity of prefrontal and frontal regions appears to be specific to mindfulness meditation. Based upon the clinical outcomes reviewed above, mindfulness meditation would appear to be the most effective form of meditation to alleviate rumination and anxiety. Indeed state and trait prefrontal asymmetries (with associated positive affect) have been reported as a direct result of modern mindfulness training, as well as individuals with increased frontal midline theta showing to have significantly lower state and trait anxiety scores than controls (Davidson et al., 2003; Inanaga, 1998). Similarly, Tang and Posner (2009) found in their review that integrative body-mind training (IMBT – largely comprised of mindfulness-attention based training), led to increased frontal theta activity, and this increased frontal theta was correlated with decreased stress, anxiety, depression, anger, and fatigue. This evidence provides a strong neurological basis for concluding that modern mindfulness training's subjective outcome does indeed have a strong basis in the change occurring within the prefrontal cortex.

4.3. Self-referential processing within mindfulness

Self-referential processing refers to the subjective and executive monitoring, or meta-awareness, of the present state of sensory consciousness (Deikman, 1982; Varela, Thompson, & Rosch, 1991). An internal essence of mindfulness is to embody the notion that the notion of 'self' is an ever changing entity; and meditation seeks to dissolve the idea of a permanent, never changing 'self' (Olendzki, 2010). Self-referential processing has been shown through self-report (Kerr, Josyula, & Littenberg, 2011) and neurological measures to be altered via mindfulness meditation (Hölzel et al., 2011a, 2011b). Research has shown the engagement of the frontal-parietal network during self-referential processing as crucial to define between the self and the 'other' (Brewer, Garrison, & Whitfield-Gabrieli, 2013; Sajonz et al., 2010), as well as the specific importance to the prefrontal and parietal cortices in self-reference (Gusnard, Akbudak, Shulman, & Raichle, 2001; Northoff et al., 2006; Sajonz et al. 2010). Functional neurological change has been found to occur in these areas as a result of mindfulness based stress reduction training (Baerentsen et al., 2001; Farb et al., 2007; Hölzel et al., 2011a, 2011b).

Research provides further support for the posterior cingulate cortex (part of the inferior parietal) as central to the subjective feeling of being consumed by an experience, as opposed to being detached and mindful of the experience (Brewer et al., 2013). Therefore, it may be hypothesised that inhibition of the inferior parietal area within spiritual practice and meditation research may suppress this feeling of being consumed by increasing attentional focus on the present. Indeed, this will provide the subjective experience of being mindful of one's own experience. A lack of self-reference has been shown to be a crucial marker in disorders of the self, such as schizophrenia and hyper-reflexivity (Sass & Parnas, 2003). One of the benefits of mindfulness meditation may therefore be a more defined sense of 'self' and 'other'.

The different methodologies used to tease apart neurological changes from meditation is a factor that can lead to seemingly contradictory results across studies. For example PET and SPECT results (Newberg et al., 2001; Newberg et al., 2003) have indicated decreased parietal activity, while fMRI research indicates increased activity. However, as discussed previously, increased blood flow revealed with PET and SPECT analyses has been correlated with increased alpha wave activity (Bazanova & Vernon, 2014; Goldman et al., 2002), which represents decreased processing in that region (Larson et al., 1998). On the other hand, fMRI analyses indicating increased blood oxygenation have been correlated with decreased alpha activity in posterior regions (Laufs et al., 2003; Goldman et al., 2002). This mixed methodology makes streamlining of results in some brain regions during meditation particularly difficult to analyse.

Replicating these experiments with similar methods and heterogeneous cohorts of participants is required in order to uncover the functional relevance of changes to brain regions in meditators. The different attributes of the participants, combined with varying neurological methodology, have led to results that are consistent in some areas but remain unresolved in others. Mindfulness-based training appears to improve self-referential awareness, and this co-occurs with changes to fronto-parietal network. Due to the confounding factor of many mindfulness studies examining mindfulness interventions within various spiritual frameworks, it is difficult to tease apart how the subjective experience of connection of a higher being influences the neural activation patterns and neuroplastic changes observed following mindfulness training and practice. Secular mindfulness-based training has been shown to produce prefrontal neurological changes associated with its subjective affect. However, how the absence of spirituality in the training affects the neurological alteration is yet to be elucidated.

To summarise, research has generally indicated that individuals who practice mindfulness meditation show significant differences in neural activity compared to individuals who do not. These changes consist of activation patterns, particularly within nodes in the fronto-parietal network. Further, fMRI and MRI research has correlated with EEG data to demonstrate changes in frontal midline theta after mindfulness based cognitive therapies and loving kindness meditation (Brewer et al., 2011; Cahn & Polich, 2006; Taylor et al., 2012).

However, evidence regarding the role of the parietal cortex during mindfulness meditation is inconsistent. Reasons for this inconsistency could be variation in the type of mindfulness meditation between studies or between participants used within a study. For example, Newberg et al. (2003), who found a decrease in blood flow in the parietal cortex, examined three experienced Franciscan nuns who used verbal meditation techniques (such as chanting) and SPECT analysis. Given the extremely low participant count in their study, further replication with a greater number of participants is required before any generalisations can be made. A review of the field by Hölzel et al. (2011a, 2011b), drawing on a wealth of studies and research, suggests that Lazar et al.'s (2000) results are the more consistent – during mindfulness meditation, an increase in inferior parietal cortex activity is found, when examining the relation to mindfulness' effect of self-reference.

As mentioned previously, evidence seems to suggest that self-reference is a balancing act within the fronto-parietal network in regard to the subjective experience of mindful detachment. Increases in activity in both cortices need to be looked as in conjunction with one another to get a full picture of their relationship. While parietal activation may appear to be occurring within one context, it may still be relatively less active than the individuals' prefrontal or frontal lobe. The outcome of prefrontal and parietal activity changes resulting from meditation, although beneficial to wellbeing, may be affected in different ways based upon the method used to achieve these subjective and neurological changes (for example whether a spiritual or secular model is used). Hence, future clinical applications will benefit from research which clearly has different cohorts of participants which have been separated based upon type of training received, to more clearly understand this cortical relationship (see Table 2).

5. Comparison between spiritual practice and mindfulness meditation

Despite the probable overlap in both process and outcomes, groups who practice spiritually but not mindfulness meditation, and groups who practice mindfulness without an R/S framework have never been directly compared in a single study to our knowledge. However, a number of studies of both mindfulness meditation and practicing R/S groups separately show overlapping neurological findings.

Firstly, as we might expect, mindfulness studies which revolve around an R/S framework show neurological changes that are generally similar to studies of individuals who practice R/S alone. For example, Johnstone et al. (2012) and Decety and Moriguchi (2007) observed an increase in frontal and prefrontal lobe activity in individuals who experienced transcendental spirituality and connection to higher self or being. Mindfulness meditation-focused studies also showed increases in prefrontal and frontal lobe activity (Farb et al., 2007; Hölzel et al., 2011a, 2011b; Ivanovski & Malhi, 2007). Across all studies looking at the three groups of R/S, meditation, or a combination of the two, consistent results are increased blood flow in the prefrontal and frontal lobes, increased cortical thickness in the prefrontal and frontal lobes, and communication between the prefrontal, frontal and parietal lobes. These changes are associated with resilience against mental disorder, greater interoceptive awareness, and reduction in symptoms of stress and anxiety (Cahn & Polich, 2006).

Secondly, the parietal cortex has been an area highlighted across all three types of studies. Meditation research has shown mixed results of increased activation of the parietal cortex, suppression, or in some cases, no difference during and after meditation (Aftanas & Golocheikine, 2001; Baerentsen et al., 2001; Dunn et al., 1999; Farb et al., 2007; Hölzel et al., 2011a, 2011b; Lagopoulos et al., 2009). R/S research however has mainly implicated the decrease or suppression in activity of the parietal cortex in practicing R/S individuals (Johnstone et al., 2012; Tenke et al., 2013; Urgesi et al., 2010). Some research in each area appears to overlap. Azari et al. (2001) for example shows that the fronto-parietal network in-fact displays increased blood flow in R/S individuals. This is in line with Hölzel et al.'s (2011a, 2011b) research. This evidence is in contrast with state changes, such as in Newberg et al.'s (2003) paper, which reports that Buddhist meditators display a decrease in parietal activity during meditation. One overlapping theme may be the role of the parietal cortex in self-referential processing. The parietal cortex has been heavily implicated in the ability to self-reference, with increased relative activity leading to greater definition between the 'self' and 'other' (Brewer et al., 2013; Lazar et al., 2000). In mindfulness meditation, the trait result in the parietal cortex is reflected with increases in relative activity, and in R/S practice, the parietal cortex has been found to decrease in relative activity.

As well as neurological activity differences between individuals who practice mindfulness and individuals who practice spiritually, it is important to examine the subjective participant beliefs in the meditation group of neuroimaging studies to see how these beliefs may affect the results. Studies that include participants who adhere to a spiritual framework may display neural activity which overlaps with research in R/S practice, and these are not shown in studies which include participants of a secular training. Therefore, we have a basis to develop future studies, which test hypotheses relating to the

Table 2
Summary of neural changes as a result of mindfulness meditation.

Author	Neurological method	Participants background	Participant no.	Main findings
Lazar et al. (2005)	MRI	'Insight' Meditators – Western meditation practitioners	35	Increased relative cortical thickness of frontal, prefrontal, and insular cortex in meditators compared to controls
Hölzel et al. (2011a, 2011b)	MRI	Participants took an 8-week MBSR training programme	33	Increased grey matter concentration in the posterior cingulate, temporoparietal junction and cerebellum after the MBSR training
Farb et al. (2007)	fMRI, MRI	Participants took an 8-week MBSR programme, or were novice during testing	36	Participants who went through the MBSR training showed functional increase of prefrontal, insular and inferior parietal cortices
Baerentsen et al. (2001)	fMRI	Experienced meditators (7–23 years)	5	fMRI taken during onset of meditation. Significant activations of left lateral globus pallidus, right inferior parietal lobe and right precentral gyrus
Brewer et al. (2011)	fMRI	Experienced mindfulness meditators	26	DMN network (posterior cingulate and medial prefrontal cortex) less activated in meditators compared to controls
Taylor et al. (2012)	fMRI	Two groups. One of experienced (av. hours = 1709) and one group of beginner meditators	Experienced $n = 12$, Beginner $n = 11$	Functional connectivity between the medial prefrontal cortex and default mode network nodes was significantly weaker for experienced meditators than beginners; however some areas exhibited significantly stronger connections than beginner meditators
Aftanas & Golocheikine (2001)	EEG	Short (less than ½ a year exp.) and long term (3–7 years exp.) meditators	27	Increased theta power in long term meditators over anterior sites, as well as anterior alpha 1 & 2 synchronisation. Short term meditators displayed posterior alpha desynchronisation
Lagopoulos et al. (2009)	EEG	Experienced Acem (secular) Meditators	18	Increased theta activity in frontal and temporal areas. Increased alpha found in parietal and central regions
Dunn et al. (1999)	EEG	Students who underwent five weeks of concentrative and mindfulness meditation training (western)	10	Mindfulness meditation specifically showed to increase alpha amplitude over central and posterior cortices
Davidson et al. (2003)	EEG	Employees part of a biotechnology corporation who underwent MBSR training (8 weeks)	25	Significant state and trait anterior activation asymmetry (associated with positive affect and disposition) as a result of meditation training
Newberg et al. (2003)	Single-Positron Emission Computed Topography	Proficient Buddhist meditators during two sessions of meditation	8	During meditation, significant increases in blood flow to the prefrontal cortex were observed, as well as significant *decreases* to parietal areas

variable of spiritual experience within mindfulness practice. All research that has examined neural activity during meditation in participants who utilised meditation within a spiritual framework, such as Buddhism found significant changes to fronto-parietal network activity during meditation and prayer (Newberg, Alavi, Baime, Mozley, & d'Aquila, 1997; Newberg et al., 2003; Herzog et al., 1990). Similarly, research has found decreases in inferior parietal lobe activity in R/S-alone individuals (Decety & Moriguchi, 2007; Johnstone et al., 2012). In contrast, studies that examined secular mindfulness training have found that these individuals showed increases to fronto-parietal connections, and *increases* in activity in the inferior parietal lobe (Farb et al., 2007; Lazar et al., 2000; Lazar et al., 2005). This difference between the two groups may suggest that relative activity in the parietal lobe, in relation with fronto-parietal networks, is oppositely affected as a result of each framework.

Another point to note is that increases in alpha power in the parietal cortex have been noted in R/S populations (Tenke et al., 2013). This increase in alpha rhythm indicates a *suppression* of processing in this area (Goldman et al., 2002), thereby effectively showing a decrease in parietal activity in R/S individuals during rest. This has been mirrored in research that looked at meditation from an R/S framework that found similar neurological suppression within this population (Newberg, Pourdehnad, Alava, & d'Aquila, 2003; Newberg et al., 2001), indicated via decreased blood flow. Secular mindfulness meditation research has also indicated the inferior parietal cortex displays increased alpha amplitude in those who have undergone western mindfulness based training (Dunn et al., 1999; Lagopoulos et al., 2009).

6. Discussion

The literature identifies three groups within the context of mindfulness meditation and R/S when conducting neuropsychological research. Studies have examined groups that underwent secular mindfulness interventions which have their roots in Buddhist and traditional practice, but do not necessarily advocate the use of a spiritual framework (such as Mindfulness Based Stress Reduction and Mindfulness Based Cognitive Behaviour Therapy). Studies have also identified groups that are explicitly tied into spiritual experience during meditation, by using cohorts of Buddhist or spiritual meditators, and groups who practice R/S but do not practice meditation.

Within each group, the literature indicates improved resilience and well-being, both of which are tied to neurological changes in the prefrontal region and its connection to subcortical structures. However, all three groups display different results regarding the inferior parietal cortex, and the prefrontal and frontal connections to this region. All three groups show altered activity in this region, however across fMRI, MRI, SPECT and EEG studies, all seem to show slightly different variations on similar themes. This refers to the varied results between studies of R/S practice and mindfulness individuals which show state and trait increases and decreases to the parietal lobe and inferior parietal cortex. However, in terms of relative activation, all groups across neurophysiological measures display a general trend of prefrontal lobe change over parietal cortex change, leading to positive cognitive and emotional change.

We hypothesise that these changes reflect different changes to self-other processing in these groups, as a result of the subjective focus that the individual takes through practice. This hypothesis is derived from research that indicates the parietal cortex is related to self-referential processing (Brewer et al., 2013; Decety & Moriguchi, 2007; Sajonz et al., 2010). An initial implication of these results may be that different styles of meditation, whether secular or spiritual, or indeed spiritual practice, may either increase the executive focus on the self or increase the focus on a higher being, respectively, leading to increased parietal cortex function in the first case, and decreased in the second case.

A second pattern in the research regards the parietal cortex in relation to prefrontal and frontal cortical activity. It has been demonstrated that both these cortices are altered by both R/S practice and meditation separately and R/S experience and meditation together, hence it may be that the different meditation or spiritual process undertaken leads to differences in the relative activation of the prefrontal and parietal interaction. That may be as a detachment from automatic behavioural responses, or whether that is towards the 'self' or in relation to the 'other'. As the posterior cingulate cortex (inferior parietal) may be implicated in the experience of becoming mindful of one's own actions (Brewer et al., 2013), it would be reasonable to hypothesise that parietal function also changes when the individual does not feel consumed by the experience at hand but is able to take a 'step-back'. Hence, when relative prefrontal activity rises above parietal activity, this may lead to the experience of being mindful and outside of one's own experience, whether that be attributed to the focus on a higher being or energy, or whether it is attributed to one's own subjective movement. This relative prefrontal activity may rise as a result of increased parietal inhibition, or indeed a strengthening of the prefrontal cortex itself. Hence, while research may show in some cases that prefrontal *and* parietal activity increases, that parietal activity decreases, or that just prefrontal activity increases, they may all point to the same relational network. It is possible that it is an *interaction* between activation patterns in these areas, rather than merely activation of certain discrete areas, that underpins the subjective phenomena reported.

Further, the decrease in activity of the parietal lobe may reflect a loss of 'self' and a directed thought upon something outside of the self. In contrast, an increase in activity may be indicative of the focal awareness of one's self over anything external. This may also play into the relationship with the fronto-parietal network, and how modulation of this connection may affect activity in both cortices. The research that focuses upon the fronto-parietal network, and specifically frontal midline theta as a result of prefrontal activation, has also to be further expanded in the R/S field. Mindfulness research has been very fruitful in demonstrating the shift from the default mode network to an increase of frontal midline theta (leading to a quelling of rumination and anxiety in participants), and we feel that further research into the R/S field may benefit from assessing these same measures. We hypothesise, from the research into R/S demonstrating increased prefrontal activation, that an increase in frontal midline theta would also be shown in R/S practice.

To elucidate which aspects of mindfulness and R/S practices are responsible for neural changes in individuals, future research should compare secular meditators (through mindfulness intervention programmes) and R/S meditators. The R/S populations show distinct functional changes, as do secular meditators and spiritual meditators, however, all groups also show overlapping patterns of results in some studies. All demonstrate qualities that are conducive to an improved quality of life through reductions in stress, anxiety, and increased compassion, and therefore examining how the different beliefs of each group interact neurologically to produce these subjective outcomes means that treatment options and understanding can be maximised. Further, while R/S populations appear to have a significant resilience against depression, some other associations with R/S practice as a clinically negative consequence have been researched, such as males' exhibiting a weak trend of increased risk for schizotypy and magical ideation (Diduca & Joseph, 1997; White, Joseph, & Neil, 1995). The role of R/S practice within neuronal inhibitory processes and cortical selective activation must therefore further be researched to highlight how exactly the R/S interplay is subjectively affecting meditational practice. In order to effectively answer this question, these three cohorts need to be structurally and functionally measured with the same techniques across each experiment to truly examine how they each neurologically compare between conditions.

If EEG, fMRI, MRI and PET measures are used in separate experiments, we suggest that there would be a large neurological overlap between populations that practice R/S and spiritual meditators, and spiritual meditators and secular meditators. We hypothesise that the most important differences between these groups will depend upon the degree of self-awareness (or 'selflessness') cultivated in each practice, which will be reflected by the parietal cortex in its rhythmic, functional and structural changes. Changes in the parietal cortex are also likely to alter the functional connectivity between the fronto-parietal network, and as such we suggest that future research examine functional connectivity through this network, as well as activity in each region alone. Research into the identification of 'self' and 'other' appear to intrinsically tie into the focal point and belief system of spiritual and secular meditation. Indeed the attribution towards what the individual believes they are connecting to may be implicitly tied to how the parietal cortex activates and changes.

Currently, there is no research to our knowledge that directly answers this question in relation to the variable of spiritual experience, and hence there is no clinical reference point into the neurological significance of the parietal and fronto-parietal region. It is necessary to compare each group with similar cortical measurements in a single study. This elucidation of neurological change between the frontal cortex, parietal cortex and fronto-parietal balance is crucial due to its basis in self-reference and its varying activation between different cohorts of participants in meditation and R/S research. Through this understanding, clinical practice could benefit in the maximisation of mindfulness meditation in its ability to instil compassion, empathy, decreased anxiety and decreased depression into those who practice it or use it for therapeutic gain. Research will be able to further capitalise upon this knowledge to inform clinical practice, and indeed improve clinical techniques used for treatment of mental health disorders.

7. Conclusions

R/S practice, secular meditation and spiritually-oriented meditation all hold potential to reduce symptoms of anxiety and depression, increase resilience and empathy, and improve well-being. Neurologically, all three groups show overlapping structural and functional changes located in the prefrontal and subcortical regions, but show inconclusive patterns of results from each other in the parietal cortex. We suggest that while all three groups display benefits in self-awareness and empathy, the difference in the R/S group is due to the subjective focal point of awareness, whether that be on the self or on an entity outside the self, and further how the individual places their sense of 'self' and 'other'. Research examining meditators who practice with a spiritual framework appear to support an idea that R/S experiences lead to decreases in parietal functionality. Further research comparing participants from all three groups, and using the same methodological techniques, will elucidate the true neurological overlap. This understanding of spiritual experience as a variable can then inform clinical practice to maximise the potential for recovery from mental illness and adverse life events. Focused work which has evidence of how spiritual or secular practices differently effect fronto-parietal networks (and associated sub cortices) can therefore be more predictive into how different forms of meditation can benefit an individual, and what subjective differences will occur. Different therapeutic measures such as EEG and fMRI can also therefore be interpreted more accurately into the neurological cause and effect of different forms of mindfulness meditation, and mixing results from different methodologies will form an increasingly coherent picture of associated neurological processes.

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