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REVIEW ARTICLE

A systematic review of neurobiological and clinical features of mindfulness meditations

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Background. Mindfulness meditation (MM) practices constitute an important group of meditative practices that have received growing attention. The aim of the present paper was to systematically review current evidence on the neurobiological changes and clinical benefits related to MM practice in psychiatric disorders, in physical illnesses and in healthy subjects.

Method. A literature search was undertaken using Medline, ISI Web of Knowledge, the Cochrane collaboration database and references of retrieved articles. Controlled and cross-sectional studies with controls published in English up to November 2008 were included.

Results. Electroencephalographic (EEG) studies have revealed a significant increase in alpha and theta activity during meditation. Neuroimaging studies showed that MM practice activates the prefrontal cortex (PFC) and the anterior cingulate cortex (ACC) and that long-term meditation practice is associated with an enhancement of cerebral areas related to attention. From a clinical viewpoint, Mindfulness-Based Stress Reduction (MBSR) has shown efficacy for many psychiatric and physical conditions and also for healthy subjects, Mindfulness-Based Cognitive Therapy (MBCT) is mainly efficacious in reducing relapses of depression in patients with three or more episodes, Zen meditation significantly reduces blood pressure and Vipassana meditation shows efficacy in reducing alcohol and substance abuse in prisoners. However, given the low-quality designs of current studies it is difficult to establish whether clinical outcomes are due to specific or non-specific effects of MM.

Conclusions. Despite encouraging findings, several limitations affect current studies. Suggestions are given for future research based on better designed methodology and for future directions of investigation.

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Key words: Mental illnesses, mindfulness, neuroimaging, physical illnesses, Vipassana, Zen.

Introduction

A particular subgroup of meditative practices known as 'mindfulness meditation' (MM) has recently received increasing attention (Bishop, 2002; Proulx, 2003; Allen *et al*. 2006). Mindfulness is currently defined in psychological terms as being characterized by paying total attention to the present moment with a non-judgmental awareness of the inner and/or outer experiences (Kabat-Zinn, 1994). It refers to the cultivation of a conscious attention on a moment-to-moment basis and is characterized by an open and receptive aptitude (Marlatt & Kristeller, 1999).

Although the concept of mindfulness has its origins in many cultural, contemplative and philosophical traditions such as Hinduism and Buddhism (Buddhaghosa, 1976), its practice does not imply following any specific philosophical or religious tradition (Kabat-Zinn *et al*. 2000). Nevertheless, MM can be considered a component of such ancient practices as Vipassana meditation (Ahir, 1999) and Zen meditation (Mizuno, 1972). In addition, clinically oriented group-based practices designed to organize the original concept of mindfulness into standardized courses for health, such as Mindfulness-Based Stress Reduction (MBSR; Kabat-Zinn, 1994, 2003) and Mindfulness-Based Cognitive Therapy (MBCT; Teasdale *et al*. 1995), can also be considered examples of MM. Note that all these meditative techniques include MM as an active feature of their practice, although significant differences can occur among them. We have grouped them together in accordance with current research on meditation, which considers these meditations as belonging to the pole of mindfulness, at the opposite of meditative practices belonging to the pole of 'concentrative meditations' such as Transcendental Meditation or Relaxation Response (Cahn & Polich, 2006; Ospina *et al*. 2007). However, we have excluded from the present review those psychotherapies that,

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although conceptually related to the concept of mindfulness, do not include the 'active ingredient' of formal sitting meditation as a component of their treatment strategy, such as Dialectical Behavioural Therapy (Linehan, 1993) and Acceptance and Commitment Therapy (Hayes *et al*. 1999).

Research studies on the biological and clinical concomitants of MM are providing increasing evidence about the short- and long-term changes that occur in mindfulness meditators (Cahn & Polich, 2006) and about clinical outcomes in physically, mentally ill and also healthy subjects related to such practices (Bishop, 2002; Grossman *et al*. 2004; Coelho *et al*. 2007). To our knowledge, however, no review has yet covered all available evidence on the neurobiological modifications induced by MM and on the clinical outcomes related to MM practices in all such conditions in a systematic way. The continuously growing evidence about MM indicates the need for updates and for an integrative systematic synthesis of current data. To address these issues, the aim of the present paper was to review current evidence on the neurobiological changes and clinical benefits related to MM practice in psychiatric and physical illnesses and also in healthy people and to provide a direction for future research.

Method

Literature research

A literature search was undertaken using Medline, ISI Web of Knowledge, the Cochrane database and references of retrieved articles. The search included papers published in English up to November 2008. The main search terms were: Buddhist mindfulness meditation, Vipassana meditation, Zen meditation, Zazen, Mindfulness-Based Stress Reduction, MBSR, Mindfulness-Based Cognitive Therapy, and MBCT.

Selection of trials

Full text articles, letters to the editor, short communications and congress abstracts indexed by the abovementioned electronic databases that focused on the relationship between MM practice and neurobiological or clinical outcomes in patients with mental and physical disorders and also in healthy people were screened independently by the reviewers in order to be considered for inclusion. Included studies had to: (1) be randomized controlled studies, controlled studies or cross-sectional studies with controls, (2) include either active (e.g. transcendental meditators) or inactive comparators, (3) provide quantitative data supported by statistical methodology, and (4) focus on neurobiological or clinical data in healthy subjects or in clinical samples. Reasons for exclusion were: (1) qualitative reports, (2) the absence of a control group, (3) statistical methodology not reported, (4) reviews and meta-analyses, and (5) admixtures of different meditation methods.

Outcome measures

The main outcome measures considered were: (1) differences between electroencephalographic (EEG) patterns in MM and controls, (2) differences between neuroimaging patterns in MM and controls, (3) differences between biological measures in MM and controls, (4) differences between clinical outcomes (e.g. an improvement in depression symptoms or a decrease in blood pressure level) in clinical samples of MM and controls and (5) differences between clinical outcomes in healthy MM and controls.

Data extraction and synthesis

The data were extracted independently by two reviewers using a comprehensive and pretested data extraction form (see appendices D1 and D2 in Ospina *et al*. 2007). Studies were grouped together according to the type of outcome investigated, as neurobiological studies and clinical studies. Neurobiological studies were further divided into: EEG studies, neuroimaging studies, attentional performance studies and biochemical studies. Clinical studies were further divided into psychiatric disorders, physical disorders and healthy subjects. The quality of controlled studies was assessed using the Jadad Scale (Jadad *et al*. 1996), and the quality of cross-sectional studies with controls was assessed using the Newcastle–Ottawa Scale (Wells *et al*. 2005). For both measures, a score $\geqslant 3$ was considered to be indicative of a high-quality study.

Results

Search results

The original search retrieved 748 papers. Of these, 622 papers were excluded because their primary focus was not the investigation of neurobiological or clinical outcomes in short- or long-term mindfulness meditators (Fig. 1). After the first screening, the inclusion and the exclusion criteria were applied to the remaining 126 papers, resulting in 74 studies being excluded and 52 being included in this review. Studies excluded after the initial screening and reasons for their exclusion are given in Tables A1 (see Supplementary online Appendix). A summary of included studies is shown in Tables A2 and A3 (see online Appendix). A graphical summary of the results is shown in Tables 1 and 2.

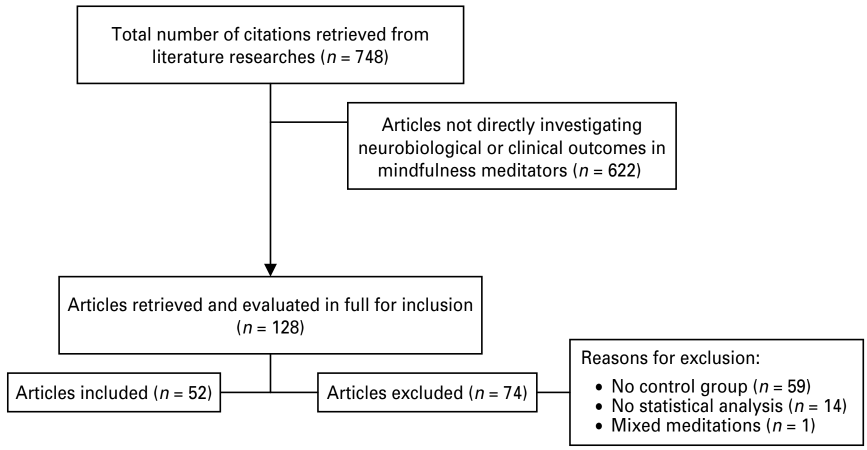

Fig. 1. Flow diagram of the review process.

Characteristics of included studies

The characteristics of the included studies are given in Tables A4 (see online Appendix).

Neurobiological evidence

EEG studies

Electroencephalography is a method that measures summed post-synaptic electrical activity of a large area of the cortex. Beta activity (12–30 Hz), an irregular wave pattern that is detected when subjects are alert and attentive, is typical of wakefulness whereas alpha (8–12 Hz) and theta (4–8 Hz) activities have been linked to different degrees of relaxation and are common findings in meditation (Cahn & Polich, 2006). There is some evidence to suggest that Zen meditation could affect EEG activity, causing a decrease in alpha frequency, frontal alpha activity and theta bursts in meditators (Kasamatsu & Hirai, 1966; Murata *et al.* 1994). The appearance of theta activity has been correlated with the level of experience (Kasamatsu & Hirai, 1966; Murata *et al.* 1994). Non-habituating alpha blocking has also been observed in Zen meditators (Kasamatsu & Hirai, 1966). Alpha blocking is defined as a decrease in ongoing alpha power when comparing pre-stimulus to post-stimulus activity. It is typically associated with alpha power reduction after closed eyes are opened (Basar *et al.* 1997; Niedermeyer, 1997). Besides alpha blocking is observed when a series of discrete stimuli are presented, such that small alpha power decreases are obtained between pre- and post-stimulus alpha activity. This effect habituates over the course of a stimulus train after 10–20 stimuli when an absence of alpha decrement from stimulus presentations is typical (Morrell, 1966; Barlow, 1985). Thus, non-habituating alpha blocking in Zen meditators could suggest the presence of a state of being relaxed but present during meditation. Unfortunately, the poor methodological quality of early findings (Kasamatsu & Hirai, 1966), only partially supported by statistic analysis, limits their generalizability and a later better designed study (Becker & Shapiro, 1981) did not detect any difference in alpha blocking between meditators and controls.

Further studies observed an effect of MBSR and MBCT on prefrontal alpha asymmetry in different populations (Davidson *et al.* 2003; Barnhofer *et al.* 2007). These meditative practices were found to provide a shift towards left-sided anterior alpha activation, a pattern associated previously with positive emotions (Davidson *et al.* 1990). One of these studies also demonstrated a possible positive correlation between the practice of MM and positive effects on the immune system (Davidson *et al.* 2003). Note, however, that methodological failures such as the absence of detailed randomization data and the cross-sectional design of some studies mean that further investigation is necessary.

Neuroimaging studies

There is some evidence based on neuroimaging studies that MM could induce specific 'state' brain modifications. Thus, Vipassana meditation practice is reported to activate the rostral anterior cingulated cortex (ACC) and the dorsal medial prefrontal cortex (dmPFC) in both hemispheres (Holzel *et al.* 2007). The authors noted that these findings suggested the possibility of meditators regulating their attentional processes by enhancements in attentional abilities related to long-term MM practice (Holzel *et al.* 2007). In accordance with such findings, long-term Zen practitioners have been found to display a reduced duration of the neural response linked to conceptual processing in regions of the default network,

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Table 1. *Neurobiological studies*

Outcome of interest	Vipassana	Zen	MBSR	MBCT
Electroencephalographic (EEG) studies				
Overall increased alpha and theta activity		+		
Alpha blocking		+**N**		
Frontal theta activity		+		
Increased frontal alpha coherence		+		
Increased left frontal alpha activity			+	+
Functional magnetic resonance imaging (fMRI)				
Thicker PFC/PFC more activated	**++**	**+**		
Thicker ACC/ACC more activated	**++**			
Thicker putamen		**+**		
Thicker right hippocampus	**+**			
Biological studies				
Reduction in stress hormones		+	**N**	
Increased antibodies			+	

PFC, Prefrontal cortex; ACC, anterior cingulate cortex. MBSR, Mindfulness-Based Stress Reduction; MBCT, Mindfulness-based Cognitive Therapy; +, MM better than control condition; N, no significant difference between MM and control condition.

Results from higher quality studies are shown in bold.

Table 2. *Clinical findings*

Outcome of interest	Vipassana	Zen	MBSR	MBCT
Psychiatric disorders				
Prevention of depression relapses in MD				**+**+
Reduction of overall depressive symptoms in MD			+	+++
Reduction of anxiety levels in BD				**+**
Social phobia				+
PTSD	N			
Alcohol and substances dependence	+			
Physical disorders				
Psychological symptoms in cancer			**++**++	
Reduction of blood pressure		++		
Chronic pain			++	
Rheumatoid arthritis			**+**+	
Fibromyalgia			++	
Psoriasis			+	
Multiple sclerosis			+	
Tinnitus				N
HIV			+	
Healthy subjects				
Stress	+	+	**+**++++++++	

MD, Major depressive disorder; BD, bipolar disorder; PTSD, post-traumatic stress disorder; MBSR, Mindfulness-Based Stress Reduction; MBCT, Mindfulness-based Cognitive Therapy; +, MM better than control condition; N, no significant difference between MM and control condition.

suggesting that meditative training could foster the ability to voluntarily regulate the flow of spontaneous mentation (Pagnoni *et al*. 2008).

Of interest, both long-term Vipassana and Zen meditation can also provide 'trait' modifications. In particular, some evidence suggests that Zen meditation might offer protection from cognitive decline through inhibition of the reduction in both grey matter volume and attentional performance associated with age (Pagnoni & Cekic, 2007). In addition, Vipassana meditation might enhance cerebral activity in brain areas related to interoception and attention, such as the PFC, the right anterior insula (Lazar *et al*. 2005; Holzel *et al*. 2008) and the right hippocampus (Holzel *et al*. 2008), cerebral areas related to attention and visceral awareness, presumably reflecting the specific training during Vipassana meditation, namely the awareness of bodily sensations.

Note, however, that the major limitation of these studies with regard to their cross-sectional design was the impossibility of controlling for baseline values so that possible baseline confounding factors cannot be excluded.

Attentional performance studies

There is some evidence that MM can improve attentional performance (Valentine & Sweet, 1999; Jha *et al*. 2007; Chambers *et al*. 2008). Mindfulness meditators have been reported to show superior attentional performance, especially in relationship to unexpected stimuli, compared to concentrative meditators and non-meditators (Valentine & Sweet, 1999; Jha *et al*. 2007). Improvements in attentional levels, then, could be related to improvements in psychological outcomes (Chambers *et al*. 2008), although methodological flaws such as the absence of randomization or of pretest values possibly related to self-selection or predisposing baseline factors bias respectively suggest that these findings should be considered with caution.

Biochemical studies

A low-quality study investigating a possible difference in the activity of serum nitric oxide, the predominant anti-atherosclerotic principle in the vascular wall, in Zen meditators and matched controls found significantly higher levels of serum nitrate and nitrite in meditators compared to controls (Kim *et al*. 2005). However, the study was strongly limited by the absence of baseline values, which could have missed possible baseline differences between the two groups. A better designed study, investigating the effects for the resting levels of stress hormones or physical functioning in a population of women with a history of heart disease who practiced MM compared to a control group, did not detect any significant difference (McComb *et al*. 2004).

Clinical studies

Psychiatric disorders

Mood disorders. Six controlled or randomized controlled studies have investigated the effects of MM, in particular MBCT, in subjects with major depression (MD) or bipolar disorders (BD). Two randomized controlled studies (one of high quality) (Teasdale *et al*. 2000; Ma & Teasdale, 2004) showed that MBCT plus treatment as usual (TAU) was significantly superior to TAU only in reducing depression relapses in patients suffering from MD with three or more past episodes. Further findings showed that a significant shift from categorical towards specific memories was found in the meditation group compared to TAU only (Williams *et al*. 2000) and that MBCT + TAU was significantly more efficacious in reducing residual depressive symptoms compared to TAU alone (Kingston *et al*. 2007). The shift from categorical towards specific memories is particularly important considering that categorical memories that tend to generalize experiences are a pattern usually associated with depression whereas specific memories are related to psychological health.

Moreover, MBCT could be a useful tool for reducing inter-episodic anxiety in bipolar patients in remission (Williams *et al*. 2008) and MBSR has shown some efficacy in reducing ruminative thinking in a sample of both depressive and anxious patients (Ramel *et al*. 2004).

Anxiety disorders. MBCT has been compared to standard group-based cognitive therapy for the treatment of social phobia (Koszycki *et al*. 2007). Although both groups displayed significant benefit in terms of depressive symptoms and overall quality of life, response and remission rates were significantly higher for patients assigned to cognitive-behavioural group therapy (CBGT). Conversely, no significant improvement was found in post-traumatic stress disorder (PTSD) symptoms in a sample of incarcerated patients who self-selected to attend a Vipassana meditation retreat or a TAU group (Simpson *et al*. 2007).

Substances and alcohol abuse. There is some evidence that Vipassana meditation could be effective in reducing the use of cocaine, alcohol and marijuana in incarcerated populations (Bowen *et al*. 2006). Decreases in avoidance of thoughts partially mediated effects of the course on post-release alcohol use and consequences, suggesting that thoughts acceptance could be a possible mechanism of action (Bowen *et al*. 2007). It is noteworthy, however, that methodological shortcomings of the studies reviewed, including the absence of randomization or of randomization details, the small sample size of most studies and the use of control groups that did not account for possible non-specific effects of meditation such as group support and teacher's care, strongly reduce the significance of the present findings and suggests the necessity for further higher quality research on this topic.

Physical disorders

Psychological symptoms in cancer. MBSR was found to significantly decrease stress symptoms in patients with different types of cancer (Speca *et al*. 2000). The number of minutes of meditation significantly predicted decreased distress and the number of sessions attended significantly predicted stress symptoms. These results were still maintained at a 6-month follow-up (Carlson *et al*. 2001). MBSR was also comparable to creative arts for patients with cancer, although greater improvements were found in the MBSR group in levels of anxiety, overall stress symptoms and mood disturbances (Garland *et al*. 2007). However, MBSR was not found to differ from a free choice control condition (for instance talking with a friend) in women with stage II breast cancer (Shapiro *et al*. 2003). As reported previously, this finding is in accordance with a possible non-specific effect of MM and does not support evidence for a possible specific effect.

Heart disease. Two low-quality controlled studies investigated the effects of 6 months of Zen meditation practice and 2 months of Zen meditation plus progressive muscle relaxation respectively *versus* blood pressure checks in patients suffering from hypertension (Stone & DeLeo, 1976; Yen *et al*. 1996). The results of a recent systematic review including a meta-analysis of these two studies (Ospina *et al*. 2007) indicated a significant decrease in diastolic blood pressure and a non-significant decrease in systolic blood pressure in meditators.

Chronic pain. Two controlled studies comparing MBSR or MBSR and concomitant massages *versus* a control waiting list (Plews-Ogan *et al*. 2005; Morone *et al*. 2008) found that these interventions were more efficacious in reducing pain and psychological distress compared to TAU and that they provided a significant increase in pain acceptance and physical function.

Rheumatoid arthritis. MBSR was found to be significantly efficacious for the treatment of patients with rheumatoid arthritis in reducing distress and improving overall well-being and marginally depressive symptoms in meditators as well (Pradhan *et al*. 2007; Zautra *et al*. 2008). However, the intervention had no impact on patients with arthritis (Pradhan *et al*. 2007). Further data suggest that MBSR could be comparable to cognitive behavioural therapy (CBT) for such patients (Zautra *et al*. 2008), albeit with a different specific profile. Although CBT was significantly better in improving pain control and in reducing levels of interleukin-6, a pro-inflammatory cytokine related to the maintenance of rheumatoid arthritis, MBSR was significantly more efficacious in reducing pain in rheumatic patients suffering from concomitant major depression.

Fibromyalgia. MBSR was also superior to active social support in patients with fibromyalgia, providing improvements in overall quality of life, coping with pain, anxiety, depression and somatic complaints (Grossman *et al*. 2007; Sephton *et al*. 2007). The benefits were still present at a 3-year follow-up (Grossman *et al*. 2007). Of note, these studies are supportive of a possible specific effect of MBSR that goes beyond the one due to social support, although absence of randomization could have led to a possible self-selection bias.

Miscellaneous findings. Four further low-quality controlled studies investigated the usefulness of MBSR for miscellaneous physical disorders. Specifically, there is some evidence suggesting the possible efficacy of MBSR for psoriasis (Kabat-Zinn *et al*. 1998), multiple sclerosis (Mills & Allen, 2000) and HIV (Creswell *et al*. 2009), whereas no significant benefit for patients with tinnitus was observed (Sadlier *et al*. 2008).

To summarize, it is possible that MM could be efficacious for the above-mentioned physical illnesses. Nonetheless, it is difficult to establish whether these benefits are related to a specific effect of these interventions or to non-specific effects, and bias related to methodological shortcomings also cannot be excluded. Further studies should be designed to overcome these limitations.

Healthy subjects

Eleven mainly low-quality controlled studies, nine focusing on MBSR (Astin, 1997; Shapiro *et al*. 1998, 2005, 2007; Rosenzweig *et al*. 2003; Cohen-Katz *et al*. 2005; Jain *et al*. 2007; Vieten & Astin, 2008; Klatt *et al*. 2009), one on Zen (Gillani & Smith, 2001) and one on Vipassana meditation (Emavardhana & Tori, 1997), investigated the effects of mindfulness-based interventions in healthy subjects. The results were consistent with an overall non-specific effect on stress reduction. A recent meta-analysis (Chiesa & Serretti, 2009) found a significant reduction in stress levels in addition to a significant improvement in spirituality levels in those who attended MBSR programmes compared to waiting list controls. Furthermore, MBSR significantly reduced many parameters, including depression, anxiety score (Astin, 1997) and rumination (Jain *et al*. 2007), and enhanced interpersonal sensitivity (Shapiro *et al*. 2005, 2007) and also more adaptive copying strategies and self-compassion. It is noteworthy that results from a single trial comparing MBSR to a control group intervention designed to be structurally equivalent to a meditation programme in terms of instructor attention, weekly and total duration and course modality (Shapiro *et al*. 2007) suggested that MBSR could also have a specific effect. Similar results were replicated for Zen meditation (Gillani & Smith, 2001).

Finally, a single non-randomized controlled study on Vipassana meditation found positive gains in all areas of self representation in meditators compared to controls (Emavardhana & Tori, 1997). In conclusion, there is some evidence of a mainly non-specific effect of MM in comparison to a waiting list control. Again, however, several limitations, including self-selection and difficulty in establishing possible specific effects of MM, suggest considering the available findings with caution.

Discussion

The aim of the present work was to systematically review current evidence about MM. We also aimed to provide an integration of these data in order to address future research on MM. Neurobiological findings suggest that MM practices are associated with changes in the activation of specific brain areas. The majority of studies focused on state changes, observing an activation of many areas such as the PFC and the ACC, and an increase in alpha and theta EEG activity, a pattern usually associated with both meditation and relaxation (Cahn & Polich, 2006). Theta activity, in particular, seemed to be found in more expert meditators, possibly leading to the hypothesis that greater experience could be related to higher ability of self-induced deep relaxation.

A major limitation of most EEG studies is, however, the presence of many methodological flaws, including the absence of randomization details or of a focus on trait changes induced by MM. This is important because almost every treatment (for instance relaxation or meditation training) is associated with state modifications but not necessarily with trait modifications (Cahn & Polich, 2006). Although one EEG study provided some evidence for a possible trait modification induced by MBCT in a sample of suicidal attempters (Barnhofer *et al*. 2007), the generalizability of this study to healthy and non-suicidal ill populations is questionable, given the incomplete methodological data and the small sample size. Thus, future EEG research should improve evidence by using adequate randomization methods, reporting randomization details, including information on possible EEG trait modifications related to meditative practice and performing analysis on larger samples.

We did find consistent evidence based on high-quality neuroimaging studies suggesting that differences between long-term mindfulness meditators and matched controls could exist. In particular, studies investigating long-term effects of MM practice found that cerebral areas and subcortical structures involved in attentional processes were thicker in expert meditators compared to controls and that meditators did not show any significant decrease in both grey matter volume and attentional performance with age. These results are in accordance with previous findings suggesting that, when a task that requires attention is consistently directed towards a behaviourally relevant sensory stimulus, robust changes in sensory cortical maps are observed (Merzenich & Decharms, 1996; Bangert & Altenmuller, 2003; Bao *et al*. 2004). It is noteworthy that these findings suggest that the cultivation of mindful attention related to voluntary regulation of PFC activity, as shown by neuroimaging studies, could be one important element in an overall reorganization of the brain activity, where voluntary sustained attention reduces excessive emotional reactivity, hence providing the basis for a more equilibrate mind–body interaction possibly related to clinical outcomes. Note, however, that the cross-sectional design of these studies does not enable us to understand whether differences between meditators and controls could exist before starting meditation training; for instance, thicker cortical or subcortical areas could be a distinctive marker of people more prone to meditation. Present evidence could be improved by investigating novice meditators and matched non-meditator controls and following them prospectively through time.

Clinical evidence suggests that MM could be useful in many psychiatric and physical disorders and also in healthy people, although these results have to be considered with caution because of the low quality of most included studies. In particular, current data suggest that MBCT could be efficacious for reducing depression relapses, MBSR showed efficacy for some psychiatric disorders, for reducing psychological distress in patients with cancer and chronic pain, for improving many physical conditions and for reducing stress levels in healthy subjects, Zen meditation practice could be related to a reduction in blood pressure and Vipassana meditation could be useful for alcohol-dependent incarcerated subjects. Our results are in accordance with a meta-analysis investigating the effects of MM on mental and physical outcomes that calculated an effect size of 0.54 for psychiatric disorders and 0.53 for physical disorders (Grossman *et al*. 2004). Our review also extends their results by specifying disorders for which different MM could be useful and including a quality assessment of the studies included.

The reviewed clinical findings raise many important issues. The first is whether MM could have a specific or a non-specific effect on clinical outcomes; from current studies it is possible to argue that MM could have a non-specific effect compared to no treatment (such as a waiting list). Nevertheless, to improve actual evidence about MM, future studies should compare MM to a control group designed to be structurally equivalent to a meditation programme in terms of instructor attention, weekly and total duration, and course modality. Thus, it should be possible to detect specific effects of MM that go beyond non-specific effects.

Second, to date, there is only little evidence of the long-term effects of MM. An investigation of long-term effects is important: first, because there is some evidence that most MM practitioners continue to meditate after the programme (Carlson *et al*. 2001; Miller *et al*. 1995); second, to exclude possible short-term placebo effects, and third, to link neurological changes observed in long-term meditators to trait clinical changes (as, for example, long-term prevention of depression relapses).

There is also an important need to operationalize the concept of mindfulness univocally. Although many attempts have already been made (Brown & Ryan, 2003; Baer *et al*. 2004, 2007; Bishop *et al*. 2004; Cardaciotto *et al*. 2008), the authors have often disagreed in considering mindfulness as a trait or a state, or as a unitary or a multiple construct. Until this issue is defined unambiguously, it will be very difficult, if not impossible, to provide a systematic and coherent framework for mindfulness, and in turn for MM, with precision.

A further important issue concerns the generalizability of the results obtained from one MM to another. It is worth mentioning that, although Zen and Vipassana meditation interventions typically involve only MM (usually after adequate training of concentrative meditation), the newer adapted group-based interventions of MBSR and MBCT combine MM with cognitive behavioural change technologies or other practices such as Hatha yoga and therefore may represent partially overlapping but distinct category of meditation interventions. In addition, on account of the admixture of different techniques, it is not possible to understand whether mindfulness itself is the 'active ingredient' of MM or not. Thus, future research could use a dismantling design to assess the differential efficacy of different components of MM.

Finally, current evidence is heavily influenced by methodological flaws, including non-randomization, randomization details not reported and small sample size related to self-selection bias, possible inappropriate statistical methodology and the higher likelihood of false-positive findings. A major limitation is represented by the difficulty to conduct meditation studies in a double-blind condition. However, this could be partially overcome through the use of at least a single-blind design, where the evaluator but not the meditator is blind to the treatment allocation, a strategy already applied by some authors.

An important limitation of the present review lies in the decision to limit the research to articles published in English so that several Eastern journals that might contain important results about mindfulness practices have not been indexed. The decision to consider four different meditation practices together, even though linked by the concept of mindfulness, could represent a limit because they cover a spectrum from pure meditative practices such as Vipassana and Zen to mixed forms such as MBSR and MBCT.

In conclusion, current evidence suggests a non-specific and a possible specific effect of MM for many psychiatric and physical disorders and also for healthy people. Nonetheless, further better designed research is needed to confirm the available findings, investigate the usefulness of these interventions for further conditions, and determine the specificity and generalizability of MM interventions.

Declaration of Interest

None.

Note

Supplementary material accompanies this paper on the Journal's website (http://journals.cambridge.org/psm).

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