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Mindfulness: Top–down or bottom–up emotion regulation strategy?

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HIGHLIGHTS

- ► Mindfulness training (MT) has shown efficacy for many clinical conditions.
- ► Little is known about the neural correlates supporting the clinical benefits of MT.
- ► MT could be associated with top–down emotion regulation in short-term practitioners.
- ► MT could be associated with bottom–up emotion regulation in long-term practitioners.
- ► Different instructions or mental conditions could influence the neural mechanisms of MT.

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ABSTRACT

The beneficial clinical effects of mindfulness practices are receiving increasing support from empirical studies. However, the functional neural mechanisms underlying these benefits have not been thoroughly investigated. Some authors suggest that mindfulness should be described as a 'top–down' emotion regulation strategy, while others suggest that mindfulness should be described as a 'bottom–up' emotion regulation strategy. Current discrepancies might derive from the many different descriptions and applications of mindfulness. The present review aims to discuss current descriptions of mindfulness and the relationship existing between mindfulness practice and most commonly investigated emotion regulation strategies. Recent results from functional neuro-imaging studies investigating mindfulness training within the context of emotion regulation are presented. We suggest that mindfulness training is associated with 'top–down' emotion regulation in short-term practitioners and with 'bottom–up' emotion regulation in long-term practitioners. Limitations of current evidence and suggestions for future research on this topic are discussed.

Contents

Abbreviations: ACC, anterior cingulate cortex; dlPFC, dorsolateral prefrontal cortex; DMN, default mode network; EF, experiential focus; fMRI, functional magnetic resonance imaging; lPFC, lateral prefrontal cortex; MBCT, mindfulness based cognitive therapy; MBIs, mindfulness based interventions; MBSR, mindfulness based stress reduction; mPFC, medial prefrontal cortex; NF, narrative focus; OFC, orbito-frontal cortex; PCC, posterior cingulate cortex; PFC, prefrontal cortex; rACC, rostral anterior cingulate cortex; sgACC, subgenual anterior cingulate cortex; vmPFC, ventromedial prefrontal cortex; vlPFC, ventrolateral prefrontal cortex; WL, waiting list.

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1. Introduction

In the last decade a surge of interest has been directed towards the exploration of mindfulness as a means to treat a variety of physical and psychological conditions (Chiesa & Serretti, 2010; Ludwig & Kabat-Zinn, 2008). Many different definitions of mindfulness exist and mindfulness is therefore differently interpreted and practiced across different mindfulness based interventions (MBIs; Chiesa & Malinowski, 2011; Malinowski, 2008). However, there is some consensus on defining mindfulness as the act of "paying attention in a particular way: on purpose, in the present moment, and nonjudgementally" (Kabat-Zinn, 1994, p.4).

The empirical evidence suggesting the beneficial effects of cultivating mindfulness has grown in both quantity and complexity in recent years. Results from randomized controlled trials are increasingly supporting the efficacy of MBIs for a large number of psychological and physical disorders (Chiesa & Serretti, 2010; Keng, Smoski, & Robins, 2011). As an example, Mindfulness based Stress Reduction (MBSR) has been found to reduce pain, stress and psychological problems in healthy individuals, chronic pain patients and cancer patients (Chiesa & Serretti, 2011a; Ledesma & Kumano, 2009; Shennan, Payne, & Fenlon, 2011). Furthermore, systematic reviews and randomized controlled trials have shown that Mindfulness based Cognitive Therapy (MBCT) might be an effective intervention for currently depressed patients as well as for the prevention of depression relapses in patients with three or more prior depressive episodes (Chiesa, Mandelli, & Serretti, 2012; Chiesa & Serretti, 2011b; Manicavasgar, Parker, & Perich, 2011; Piet & Hougaard, 2011). These findings are in line with traditional accounts of mindfulness suggesting that significant positive changes occur in the psycho-physiological processes of individuals cultivating mindfulness in their daily life (Grabovac, Lau, & Willet, 2011; Olendzki, 2006). Until recently, however, the mechanisms behind the effects of mindfulness practice were relatively unknown to Western psychology and neurobiology (Chiesa, Brambilla, & Serretti, 2010).

To address the current gap, several authors have recently examined the mechanisms of mindfulness within the context of emotion regulation strategies (e.g. Chambers, Gullone, & Allen, 2009; Garland et al., 2010; Hoffman & Asmundson, 2008). Emotion regulation can be defined as the ability to regulate one's own emotions and emotional responses (Gross, 1998a, 1998b). Current evidence suggests that there are several partially overlapping ways by which an individual can regulate his/her own emotions (Gross, 1998b; Gross & Munoz, 1995). However, at least two distinct emotion regulation strategies have been clearly distinguished from one another (Chiesa et al., 2010; Gross, 1998a; Gross & John, 2003, for a more detailed description see below). In particular, some emotion regulation strategies, such as cognitive reappraisal, are thought to manipulate the input to the emotion-generative system by actively reinterpreting emotional stimuli in a way that modifies their emotional impact (Gross, 1998b). This kind of emotion regulation has been found to involve a "top–down" regulation of prefrontal brain regions on emotion-generative brain regions, such as the amygdala (Lorenz, Minoshima, & Casey, 2003; Quirk & Beer, 2006).

Another way to regulate one's own emotions has been described as a direct modulation of emotion-generative brain regions without cognitively reappraise emotionally salient stimuli (e.g. Chambers et al., 2009; Westbrook et al., 2011). This kind of emotion regulation strategy has been termed "bottom–up" because it is characterized by a direct reduced reactivity of "lower" emotion-generative brain regions without an active recruitment of "higher" brain regions, such as the prefrontal cortex (PFC; e.g. van den Hurk, Janssen, Giommi, Barendregt, & Gielen, 2010 Westbrook et al., 2011).

There is currently no consensus as to how mindfulness practice helps regulate disruptive emotions (Chambers et al., 2009; Garland et al., 2010; Hoffman & Asmundson, 2008). According to some authors, mindfulness should be described as a top–down emotion regulation strategy facilitating positive cognitive reappraisal (Garland, Gaylord, & Park, 2009; Garland et al., 2010). According to this view, the psychological and neurobiological mechanisms of MBIs would not be significantly different from those observed in common Western psychological approaches, such as psychotherapy (Chiesa et al., 2010; Garland et al., 2009, 2010). On the other hand, other authors have argued that mindfulness could be best described as a bottom–up emotion regulation strategy (e.g. Chambers et al., 2009; Grabovac et al., 2011; Lutz, Dunne, & Davidson, 2008). Still other authors have claimed that the relationship existing between mindfulness training and different emotion regulation strategies, as well as with the activation of related brain areas, could vary as a function of overall mindfulness experience (Taylor et al., 2011).

A better understanding of whether mindfulness involves a top–down or a bottom–up emotion regulation strategy could have important clinical implications. As an example, if mindfulness training is primarily a bottom–up process, MBIs might be effective for patients not responding to traditional psychotherapies. Indeed, psychotherapy frequently relies upon top–down mechanisms, such as cognitive reappraisal, to regulate unpleasant emotions (DeRubeis, Siegle, & Hollon, 2008; Roffman, Marci, Glick, Dougherty, & Rauch, 2005). However, the possibility to reappraise one's own emotions is often impaired in psychological disorders (e.g. Keightley et al., 2003; Liotti, Mayberg, McGinnis, Brannan, & Jerabek, 2002). As a consequence, the effects of MBIs might be superior to the effects of traditional psychotherapies for patients with an impairment of their ability to reappraise unpleasant emotions.

Neuro-imaging studies focusing on the exploration of mindfulness practice and employing emotion regulation paradigms might provide particularly fruitful insights into the understanding of mindfulness as a specific emotion regulation strategy (Chambers et al., 2009; Garland et al., 2010; Lutz, Dunne, & Davidson, 2008). Indeed, they could allow for the understanding of which brain areas are activated or deactivated when mindfulness practitioners are asked to regulate their own emotions during tasks that require emotional regulation. This, in turn, would help clarify whether mindfulness could be best described as a bottom–up or as a top–down emotion regulation strategy, as well as related clinical implications. The aim of this review is, therefore, to assess whether mindfulness practice can be best described as a top–down emotion regulation strategy, as a bottom–up emotion regulation strategy, or as a combination of both strategies, on the basis of functional neuro-imaging studies employing emotion regulation paradigms.

First, we will explore critical issues concerning current discrepancies in the definitions of mindfulness. Then, we will review current studies investigating the functional neural correlates of mindfulness training that are relevant for the understanding of mindfulness within the context of emotion regulation strategies. Finally, we will present a preliminary theoretical integration of our findings and will provide suggestions for future research on this topic.

2. Critical issues related to the definition of mindfulness

Early descriptions of mindfulness can be found in traditional Buddhist scriptures such as the Abhidhamma (Kiyota, 1978) and the

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Vishuddimagga (Buddhaghosa, 1976). The original term of what is commonly referred to as mindfulness is *Sati*, a Sanskrit word that has been both used to indicate a lucid awareness of what is occurring within the phenomenological field and as a term that could be translated as "remembrance" or memory (Bhikku Bodhi, 2011). Indeed, mindfulness has traditionally been defined as an understanding of what is occurring before or beyond conceptual and emotional classifications about what is taking or has taken place (Brown, Ryan, & Creswell, 2007). Mindfulness has also been defined as a development of one's own memory (Bhikku Bodhi, 2011). This, in turn, is supposed to enhance the ability not to forget the ethical consequences of one's own behaviours and to exploit this increased ability so as to facilitate one's own ethical development, as it is emphasized by traditional mindfulness practices (Analayo, 2006).

Although classical descriptions of mindfulness have long been highly regarded within the traditional contexts in which mindfulness practice originally developed, several authors have recently underscored that traditional descriptions of mindfulness cannot be easily translated within current Western theoretical frameworks (Grabovac et al., 2011; Grossman, 2008; Rapgay & Bystrisky, 2009). Accordingly, these authors have attempted to provide both qualitative (Bishop, 2002; Shapiro, Carlson, Astin, & Freedman, 2006) and quantitative (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006; Brown & Ryan, 2003; Lau et al., 2006) definitions of mindfulness that could be employed by current research.

Note, however, that recent publications have questioned if the original descriptions of mindfulness are comparable with the definitions provided by contemporary researchers (Grossman, 2011; Rapgay & Bystrisky, 2009). Such an issue is particularly important if one considers that in the past decades several authors have attempted to conceptualize mindfulness as a construct (e.g. Baer, Smith, & Allen, 2004; Brown & Ryan, 2003). However, in line with classical literature on this topic, mindfulness practitioner and clinical research communities are increasingly regarding mindfulness as a non-conceptual phenomenological attentional process (Grabovac et al., 2011; Grossman, 2011; Kang & Whittingham, 2010). The possibility to achieve an unequivocal understanding of mindfulness is further limited by the confusion deriving from the use of the same term 'mindfulness' in different contexts, including: (1) a specific state that arises only when the individual is purposely attending to present moment experience, (2) a mental trait that differs both among and within different individuals at different time points, and (3) specific practices designed to cultivate and maintain the state of mindfulness (Chambers et al., 2009; Davidson, 2010; Williams, 2010).

In an attempt to reduce current confusion derived from these different definitions of mindfulness, we will limit the focus of the present review to short and long-term trainings that are specifically concerned with mindfulness meditation practices. The rational for such a choice is described in more detail in the paragraphs below. For clarity, we have chosen to classify and describe the different mindfulness practices included in the present review into three groups: (1) modern clinical MBIs, such as MBSR and MBCT, that have been specifically developed to integrate the essence of ancient Buddhist practices with the modern clinical practice as a means to reduce a variety of physical and psychological symptoms (Keng et al., 2011); (2) traditional intensive mindfulness practices such as Vipassana (Gunaratana, 2002) and Zen (Kapleau, 1965) meditations that could provide information about the neural correlates of advanced mindfulness practitioners and (3) brief mindfulness inductions (e.g., brief experimental manipulations in which mindfully attending to present moment experience is taught over the period of one or more short-term sessions). These brief mindfulness inductions might, indeed, provide information about the very short-term effects of mindfulness training on brain activity.

Of, note, in the present paper we have considered subjects addressed to a brief mindfulness induction as well as those addressed to modern MBIs as short-term practitioners. On the other hand, we have considered subjects with extensive practice (such as subjects with 1 or more years of meditation experience usually included in cross-sectional studies) as long-term practitioners. At the same time, we underscore that such a dichotomy is more an artificial but useful classification rather than a clear and neat distinction. Also, although we have chosen to classify the different mindfulness practices mentioned above into three different groups, we believe that these different practices should be considered as highly correlated with one another. As an example, both short and long-term mindfulness trainings rely on repeated daily mindfulness inductions.

On the other hand, this review will not focus on mindfulness as a dispositional mental trait, on modern MBIs that are not mainly based on meditation practices and on Langer's (1989) *definition* of mindfulness. Indeed, when mindfulness is considered as a dispositional mental trait, it is not possible to distinguish the effects of explicit mindfulness training from distinct biological predispositions and environmental circumstances (Davidson, 2010). Furthermore, the measurement of mindfulness as a mental trait relies on the assumption that mindfulness can be properly assessed by existing questionnaires designed for this purpose. As mentioned above, however, there is no complete consensus about the actual relationship existing between these questionnaires and the original descriptions of mindfulness (Chiesa, 2012; Grossman, 2011; Rapgay & Bystrisky, 2009).

Also, we will only focus on MBIs that are based upon specific meditation techniques. Indeed, a comparative analysis of different mindfulness-based approaches currently subsumed under the rubric of mindfulness has recently suggested that significant differences could exist as to how mindfulness is defined and practiced across interventions employing and those not employing meditation practices (Chiesa & Malinowski, 2011). Furthermore, no relevant neuro-imaging study has been published investigating the functional neural correlates of MBIs that are not based on specific meditation practices. Finally, the definition of mindfulness employed by Langer will not be included because it is both theoretically and practically different from the traditional descriptions of mindfulness (Langer, 1989, 1997).

3. Mindfulness as an emotion regulation strategy

Emotion regulation can be defined as the ability to regulate emotions and emotional responses (Gross, 1998b). The interest towards emotion regulation relies on the notion that adaptive emotion regulation is supposed to subsume adaptive functioning and mental health (Gross & Munoz, 1995). Indeed, deficits of emotion regulation can be found in a large number of psychiatric disorders (Gross & Munoz, 1995; Repetti, Taylor, & Seeman, 2002).

There is not yet complete consensus as to how emotion regulation should be properly defined and how different emotion regulation strategies should be unequivocally conceptualized and classified (Gross, 1998b). However, in the last two decades it has been suggested that at least two distinct types of emotion regulation should be distinguished from one another: antecedent- and response-focused emotion regulation strategies (Gross, 1998a; Gross & John, 2003). Antecedent-focused strategies, such as cognitive reappraisal, are thought to represent manipulation of input to the emotion-generative system. On the other hand, response-focused strategies, such as expressive suppression, are thought to manipulate the output of the system.

Expressive suppression represents a process of consciously inhibiting emotional expression when the individual is emotionally aroused (Gross, 1998b). Expressive suppression might be useful under specific circumstances. As an example, it might be useful when one needs to inhibit escalation of disruptive emotions (e.g. anger, Butler et al., 2003). However, increasing evidence is suggesting that the repeated use of emotional suppression could lead to several negative consequences, such as a decreased experience of positive emotions (Gross & Levenson, 1997), increased rumination regarding negative mood and self-image and higher incidence of depression (Gross & John, 2003). Note, however, that other

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theoretical models suggest that the experience of disruptive emotions, such as anger, does not necessarily parallel one's behavior in the face of such emotions (Gardner & Moore, 2008).

On the other hand, cognitive reappraisal involves actively re-interpreting emotional stimuli in a way that modifies their emotional impact (Gross, 1998b). This strategy has been associated with several beneficial effects. As an example, it was found effective and adaptive for down-regulating intense negative emotions (Ochsner & Gross, 2004). Furthermore, it was found to be more adaptive than both no attempt to regulate emotions and the use of expressive suppression in several conditions (Sheppes & Gross, 2011). Current evidence about the neural correlates of emotion regulation strategies mainly suggests that cognitive reappraisal involves a top–down regulation of lateral prefrontal regions on emotion-generative brain regions, such as the amygdala, possibly by means of inhibitory connections of the orbito-frontal cortex (Lorenz et al., 2003; Ochsner & Gross, 2004, 2005; Quirk & Beer, 2006).

In the present review special attention will be given on the relationship existing between mindfulness and reappraisal as a means to understand whether mindfulness could be best described as a top–down or as a bottom–up emotion regulation strategy. Indeed, in the last decade different authors have alternatively suggested that mindfulness could be an emotion regulation strategy significantly different from cognitive reappraisal related to bottom–up mechanisms, or that it could be a coping strategy facilitating positive reappraisal associated with bottom–up mechanisms (e.g. Chambers et al., 2009; De Silva, 1990; Garland et al., 2010; Hoffman & Asmundson, 2008).

The first of these two claims describes mindfulness as a specific emotional strategy relatively unknown to Western psychology. This strategy is thought to involve "a systematic retraining of awareness and non-reactivity, leading to defusion from whatever is experienced, and allowing the individual to more consciously choose those thoughts, emotions, and sensations they will identify with rather than habitually reacting to them" (Chambers et al., 2009, p. 569). According to this view, reappraisal strategies significantly differ from mindfulness. Indeed, in reappraisal strategies "thoughts and emotions are treated as having some kind of inherent existence, and thus must be acted upon in some way" (Chambers et al., 2009, p. 569). On the other hand, "mindfulness holds that all cognitive and emotional phenomena are merely mental events, and therefore they do not need to be acted upon". Rather, "a capacity to simply allow these mental events to come and go is systematically developed" (Chambers et al., 2009, pp. 566–567). According to this claim mindfulness training involves the development of a greater ability to "stay in touch" with whatever is experienced within the phenomenological field with no need to actively regulate or reappraise what is experienced.

The second claim (Garland et al., 2009, 2010) suggests that "the state of mindfulness may be an intrinsic and central element within meaning-based coping strategies … that facilitates positive reappraisal" (Garland et al., 2010, p. 857). According to this view, "although reappraisal has recently been conceptualized as antithetical to mindfulness due to the supposition that reappraisal requires identification with and aversion toward the original stress appraisal, … the state of mindfulness is a key mechanism that makes reappraisal possible (Garland et al., 2010, p. 858). According to these authors, mindfulness and reappraisal could represent different but complementary stages of the same emotion regulation process.

Interestingly, one could speculate that these two different descriptions of mindfulness reflect the two different viewpoints of mindfulness alternatively described as a construct or as a non-conceptual phenomenological process (e.g. Brown & Ryan, 2003; Kang & Whittingham, 2010). In particular, the description of mindfulness as a construct could be consistent with the proposed top–down mechanism. According to this perspective, mindfulness can be unambiguously conceptualized and can be described as a mental trait virtually present in everybody that can be quantified and measured (e.g. Brown & Ryan, 2003). On the other hand, the description of mindfulness as a non-conceptual phenomenological process could be more in line with the proposed bottom–up mechanism. According to this perspective, any attempt to fully describe mindfulness as a concept or as a construct fails to consider the primarily non-conceptual nature of mindfulness (Grabovac et al., 2011; Grossman, 2011; Kang & Whittingham, 2010). In particular, mindfulness would not be related to conceptual thinking associated with prefrontal areas. Rather, it would allow for an understanding of what is occurring within the phenomenological field that it is not mediated by conceptual and emotional classifications about what is taking or has taken place (Grabovac et al., 2011).

Different mental processes have been linked with the activation of different, although partially overlapping, brain areas (Cabeza & Nyberg, 2000). Furthermore, distinct emotion regulation strategies have been found to involve different brain mechanisms (Gyurak, Gross, & Etkin, 2011; Kim & Hamann, 2007). As a consequence, functional neuro-imaging studies employing paradigms aimed at evoking some sort of emotion regulation, such as studies investigating the effects of mindfulness training on tasks with emotional valence (for a review see Ochsner & Gross, 2005) or on painful stimuli (for a review see Wiech, Ploner, & Tracey, 2008), could provide fruitful information about the relationship existing between mindfulness and reappraisal (Ochsner & Gross, 2005). More broadly, these studies might shed light on whether mindfulness can be best described as a top–down or as a bottom–up emotion regulation strategy. In the next section a description of a possible confounding factor in neuro-imaging findings will be briefly reviewed. Following this section, two possible scenarios as to how mindfulness training could affect brain areas' activation will be explored.

4. The default mode network

Research has identified a default-mode network (DMN) of brain regions active when the brain is not engaged in task-induced activity (Buckner & Vincent, 2007; Gusnard, Akbudak, Shulman, & Raichle, 2001). The DMN is characterized by specific coherent low frequency neuronal oscillations (<0.1 Hz) (Buckner & Vincent, 2007) localized in the medial prefrontal cortex (mPFC), posterior cingulate cortex (PCC), precuneus, anterior cingulate cortex (ACC), parietal cortex, and sometimes also the hippocampus (Buckner, Andrews-Hanna, & Schacter, 2008; Buckner & Vincent, 2007). These regions show a specific temporally coherent network of brainwave patterns in the 'resting' state of the brain (Buckner & Vincent, 2007; Northoff & Qin, 2011) while many of the DMN regions show reduced activity during externally stimulus-induced brain activity (Buckner & Vincent, 2007; Northoff & Qin, 2011). However, only minor specific DMN regions are deactivated during goal-directed activity in relation to tasks requiring self-referential thought (Broyd et al., 2009; Qin & Northoff, 2011). Moreover, studies have shown that, for instance, hearing one's own name seem to result from a specific kind of interaction between the resting state of the brain and stimulus-induced activity (Qin & Northoff, 2011) Accordingly, the DMN seems to be significantly involved in our sense of self. It has also been put forth that the activation and interaction of different parts of the DMN may simply reflect the way the mind wanders during self-referential mental processing (Broyd et al., 2009).

The DMN has been described as a task-negative network because of the antagonism between the brain's task performance patterns (Broyd et al., 2009). DMN activity persists to a substantial degree during early stages of sleep and during simple tasks in which satisfactory task performance is possible with minimal attentional resources (Greicius, Krasnow, Reiss, & Menon, 2003; Wilson, Molnar-Szakacs, & Iacoboni, 2008). A second anti-correlated task positive network is activated during task oriented brain activity (Broyd et al., 2009). The close temporal linkage and anti-correlation between the task-negative and task-positive network may allow them both to be considered components of a single default network (Buckner & Vincent, 2007; Sonuga-Barke & Castellanos, 2007). Note, however, that a

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number of additional resting state networks have been identified in other regions of the brain, and evidence indicates that multiple networks seem to be involved when the brain is not involved in task-induced activity (Broyd et al., 2009; Mantini, Perrucci, Del Gratta, Romani, & Corbetta, 2007).

5. Different conceptions of mindfulness as an emotion regulation strategy

On the basis of reviewed findings two main conceptions of mindfulness could be hypothesized. The first conception suggests that mindfulness training can be described as an increased attention to present moment experience with a non-judgmental attitude and no attempt to cognitively reappraise emotionally salient, particularly unpleasant, stimuli (Brown et al., 2007; Chambers et al., 2009; Gunaratana, 2002; Hart, 1987). This is a clear description of a bottom–up process. Accordingly, mindfulness training should be associated with reduced activation of limbic regions (such as the amygdala and the striatum) in response to emotionally salient stimuli without concomitant activation of PFC areas, particularly dorsolateral PFC (dlPFC), ventrolateral PFC (vlPFC) and OFC (Chambers et al., 2009; Gyurak et al., 2011). Indeed, the activation of the dlPFC has been associated with attempts to actively regulate and reappraise negative affective states (Ochsner & Gross, 2005; Wiech et al., 2006) and with the dynamic representation of multiple future events in problem solving situations (Mushiake et al., 2009; Tanji, Shima, & Mushiake, 2007). Furthermore, the activation in the vlPFC, particularly right vlPFC, has been observed in neuro-imaging studies focusing on reappraisal strategies as well (Wiech et al., 2006). However, there is not yet complete consensus about the differential role of this area in comparison with that of the dlPFC (Wiech et al., 2008). Finally, the activation of OFC has been implicated in the regulation of affective responses by manipulating the contextual evaluation of sensory events (Rolls & Grabenhorst, 2008) and by processing reward value (Petrovic & Ingvar, 2002).

The second conception of mindfulness as an emotion regulation strategy describes mindfulness as a central element facilitating positive reappraisal. Accordingly, one could hypothesize that mindfulness training is more likely to act in a top–down manner and recruits PFC regions associated with emotional reappraisal (Ochsner & Gross, 2005; Rolls & Grabenhorst, 2008; Wiech et al., 2008). These PFC areas, in turn, could modulate limbic activity (Ochsner & Gross, 2005; Rolls & Grabenhorst, 2008). In this case, the regions modulated by mindful attention would be more strongly functionally connected to these PFC regions during mindfulness practice (Farb et al., 2007, 2010).

Additionally, both cognitive monitoring and executive attention on the one hand and sensory awareness on the other are thought to be enhanced by mindfulness training (Chiesa, Calati, & Serretti, 2011; Hölzel et al., 2011). Therefore the activation of the ACC, associated with the former functions (Bush, Luu, & Posner, 2000; van Veen & Carter, 2002), and of the insula, associated with the latter one (Craig, 2009), could be observed during mindfulness practice. As reported above, however, a functional connection between these areas and PFC areas could be observed or not depending on whether mindfulness training involves or does not involve a reappraisal of emotionally salient stimuli. Particular attention will be given to the ACC. Indeed, the activation of this area has been described as part of the DFM (Buckner & Vincent, 2007). Furthermore, the activation of this area has been shown to vary as a function of meditation experience (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007).

Finally, we propose that different neural correlates of mindfulness training, corresponding to different emotion regulation strategies, could vary as a function of: (a) of the amount of meditation practice (e.g. long-term vs. short-term mindfulness meditators), (b) study design (investigation of mindfulness vs. rest), (c) type of employed task (e.g. the use of emotional verbal stimuli vs. the use of painful stimuli) and (d) specific definition on mindfulness (mindfulness properly defined as a non-judgmental open monitoring of the whole field of awareness vs. mindfulness defined as a practice akin to concentrative practices, such as focused attention on the sensations of the breath (Lutz, Dunne, & Davidson, 2008; Lutz, Slagter, Dunne, & Davidson, 2008). As a consequence, we will pay particular attention to specific differences across the studies with regard to these considerations (see Tables 1 and 2 and the following two section).

6. Studies suggesting bottom–up regulation

Five studies have suggested that mindfulness training could reduce emotional reactivity without concurrent activation of modulatory PFC regions. Four of these studies employed a cross-sectional design (Gard et al., 2011; Grant, Courtemanche, & Rainville, 2011; Taylor et al., 2011; Westbrook et al., 2011) whereas a single study employed a prospective design (Goldin & Gross, 2010). Building on current findings suggesting that MBIs could be effective for smoking cessation (e.g. Altner, 2002; Davis, Fleming, Bonus, & Baker, 2007), a recent uncontrolled cross-sectional study focused on a large sample of 47 meditation-naive treatment-seeking smokers who were abstinent from smoking from at least 12 h (Westbrook et al., 2011). The authors assessed the neural correlates of a brief mindfulness induction in individuals wishing to quit smoking. Subjects were presented with smoking clips aimed at evoking craving and with neutral clips (Gilbert & Rabinovich, 1999; Lang, Bradley, & Cuthbert, 1997). The subjects were instructed to either just look at these two different clips or to 'mindfully' observe them. Smoking-related images were balanced between the "look-smoking" and "mindful-smoking" conditions, so that the average craving score did not differ between the two conditions. In the "look" condition, participants were asked to relax and view the picture as naturally as possible. For the "mindfully attend" condition, participants were instructed to actively focus on their responses to the picture, including thoughts, feelings, memories and bodily sensations, while maintaining a nonjudgmental 'mindful' attitude toward those responses. Furthermore, instructions explicitly asked participants to 'notice and accept' their internal experience. This description can be considered as consistent with the definition of mindfulness as an open monitoring of the whole field of experience (Lutz, Slagter, Dunne, & Davidson, 2008).

Looking at smoking images produced the highest self-reported craving, followed by mindful attention to smoking images. Looking at neutral images produced the lowest self-reported craving. The authors further observed that the look-smoking condition was associated with an increased activity in several areas including the subgenual ACC (sgACC). Most importantly, mindful-smoking was associated with reduced activity of bilateral sgACC and ventromedial PFC (vmPFC) as compared with the look-smoking condition. The search of areas in the PFC showing increased activity during the mindful-smoking vs. the look-smoking conditions did not provide any significant results. Post-hoc analyses showed that the sgACC was activated by passive looking at smoking images. A functional connectivity analysis further revealed that the sgACC cluster showed reduced functional connectivity with other craving-related regions, including bilateral insula and ventral striatum, during the mindful-smoking condition as compared with the look-smoking condition.

Overall, the results of this study are consistent with a reduced reactivity rather than with an increased regulation of craving-inducing stimuli associated with the mindfulness condition. However, this study has a number of methodological limitations. First of all, the possibility of a positive expectancy effect related to mindful attention instructions cannot be ruled out. However, the authors did not intentionally describe mindfulness as a strategy aimed at reducing craving. Also, the lack of a comparison group as well as of a pre-post design do not allow to infer a causal relationship between increased mindful attention to stimuli and observed altered neural correlates. Finally, the

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Table 1
Main characteristics of included studies: Study design: CC = case–control study; RCT = randomized controlled study; UCT = uncontrolled study; Mindfulness condition/control condition: BMI = brief mindfulness induction; MBSR = Mindfulness based Stress Reduction; WL = waiting list; Main findings: L = left; R = right; ACC = anterior cingulate cortex; dlPFC = dorsolateral prefrontal cortex; INS = insula; OFC = orbitofrontal cortex; PCC = posterior cingulate cortex; PFC = prefrontal cortex; sgACC = subgenual anterior cingulate cortex; VS = ventral striatum.

Author (date)	Study design	Type of subjects	Mindfulness condition/ control condition	Number of subjects	Main findings
Intervention studies					
(Farb et al., 2007)	RCT	Healthy	MBSR WL	20 16	Subjects randomized to MBSR showed a significant reduction in the activity of the mPFC as compared with subjects randomized to the WL as well as increased engagement of a right lateralized network, including the lateral PFC and viscerosomatic areas such as the insula. Functional connectivity analyses demonstrated a strong coupling between R INS and R dlPFC in MBSR completers
(Farb et al., 2010)	RCT	Healthy	MBSR WL	20 16	In spite of equivalent self-reported sadness following a sad mood induction, subjects randomized to MBSR demonstrated a distinct neural response, with greater R-lateralized recruitment, including visceral and somatosensory areas that was associated with decreased self-reported depression scores
(Goldin & Gross, 2010)	UCT	Social phobia	MBSR	16	Breath-focused attention task was associated with reduced amygdala activity and increased activity in visual attention areas such as the precuneus and the superior and inferior parietal lobule as compared with the distraction-focused attention task
(Zeidan et al., 2011)	UCT	Healthy	BMI	15	Following the mindfulness induction, meditation-induced reductions in pain intensity ratings were associated with increased activity in the ACC and anterior insula, whereas reduction in pain unpleasantness ratings were associated with OFC activation.
Cross-sectional studies					
(Gard et al., 2011)	CC	Healthy	Vipassana Controls	17 17	Long-term mindfulness practitioners showed reduced activation of the lateral PFC and increased activation in the R posterior INS in relationship to a noxious stimulus as compared with novices while practicing mindfulness
(Grant et al., 2011)	CC	Healthy	Zen Controls	13 13	Meditators receiving a painful stimulation showed reduced activity in executive, evaluative and emotion areas during pain, including the PFC, amygdala and hippocampus that was larger in more experienced meditators as compared with controls. At the same time, they more strongly showed activation in primary pain processing regions such as the INS, thalamus and ACC
(Taylor et al., 2011)	CC	Healthy	Zen Novices	12 8	During meditation, expert mindfulness meditators showed a significantly larger deactivation of the default mode network areas, including medial PFC and PCC across all valence categories and no significant activation in brain regions involved in emotional reactivity during emotional challenges as compared with novices. On the other hand, for beginners relative to experienced meditators, mindfulness induced a down-regulation of the left amygdala during emotional processing.
(Westbrook et al., 2011)	UCT	Smokers wishing to quit smoking	BMI	47	Mindfully attending to smoking images reduced neural activity in a craving-related region of sgACC and reduced functional connectivity between sgACC and other craving-related regions including bilateral insula and VS compared to passively viewing smoking images

extent to which results related to this brief mindfulness manipulation can be generalized to longer mindfulness trainings is unclear.

To better establish the effects of long-term mindfulness meditation practice, three further studies investigated the neural correlates of mindfulness in long-term mediators in comparison with non meditators or novice meditators matched for several socio-demographic variables such as gender, age and education level. Grant et al. (2011) compared the neural correlates of 13 long-term Zen meditators with those of 13 non meditators employing a thermal pain paradigm. In this study, a thermal stimulator was used for pain induction. Each participant's moderate-pain level (between 47 and 53 °C) was used for pain while 43 °C was used for warm condition for all subjects. Meditators were explicitly asked not to meditate during the scan. Following each functional scan participants rated the intensity and unpleasantness of the painful stimuli.

Consistently with previous reports (Grant, Courtemanche, Duerden, Duncan, & Rainville, 2010; Grant & Rainville, 2009), meditators required significantly higher thermal stimulus intensities than non-meditators before they reported moderate pain. However, an independent sample t-test confirmed that pain intensity and unpleasantness ratings were not different between groups during the fMRI scans. Significantly stronger pain-activation was found for meditators within the dorsal ACC, thalamus and insula. In contrast, controls showed stronger activation in several areas including bilateral dlPFC and amygdala as well as left medial PFC (mPFC) and OFC. Importantly, in most areas, group differences were not simply accounted for by the higher stimulus intensity required to elicit comparable ratings of pain in meditators. In addition, longer meditation experience was associated with lower responses in pain-related areas, such as the dorsal ACC, thalamus and insula. Furthermore, greater pain-related decreases were observed in prefrontal regions, including the dlPFC, mPFC and OFC. Also, for the meditation group, left dlPFC activity predicted pain intensity ratings. In particular, greater activity reduction was associated with lower intensity ratings. No regions were found that predicted pain unpleasantness in meditators. On the other hand, for controls, more activations in right dlPFC and left insula were associated with higher pain ratings. Finally, a functional connectivity analysis revealed that meditators had stronger connectivity between several areas including dorsal ACC, bilateral putamen and left insula during painful vs. warm stimuli. In sharp contrast, controls displayed stronger connectivity between dorsal ACC and right dlPFC. Finally, the meditators displaying the lowest pain sensitivity had the weakest correlations between dorsal ACC and dlPFC.

The authors interpreted the results of their study by suggesting that non-meditators recruited PFC areas to regulate pain perception. On the other hand, regulation of pain perception in meditators did not require explicit cognitive manipulation. Also, the authors put forth the possibility that their findings linking largest reductions in dlPFC with the lowest pain rating in meditators could support the notion of a learned state. The association between brain areas associated with pain perception and those associated with cognitive reappraisal could be replaced, in meditators, by a different network of connections of areas involved with viscero-somatic awareness (Grant et al., 2011). Note, however, that the cross-sectional design of this study does not allow to infer causality as to whether specific differences in Zen meditators are actually the result of mindfulness practice or they simply reflect differences in baseline characteristic in subjects more prone to practice Zen meditation. Furthermore, this study did not investigate the state of mindfulness but rather studied a resting state in mindfulness meditators, making the implicit assumption that repeatedly cultivating a state of mindfulness by means of mindfulness practice results in neural

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Table 2
methodological details of included studies: N.A. = not applicable; BMI = brief mindfulness induction; MBSR = Mindfulness based Stress Reduction; waiting list.

Author (date)	Mindfulness condition/ control condition	Main practice(s) (active conditions only are described)	Study duration	Number and duration of meetings	Attentional focus task(s)	Concomitant task(s)
Prospective studies						
(Farb et al., 2007)	MBSR WL	Body scan, mindful stretching, mindfulness of breath/body/sounds/thoughts (henceforth "common MMP exercises")	8 weeks	8 weekly 2 h meetings	Experiential focus vs. narrative focus	Viewing mildly positive and negative personality trait adjectives
(Farb et al., 2010)	MBSR WL	Common MMP exercises	8 weeks	8 weekly 2 h meetings	N.S.	Viewing neutral vs. sadness inducing clips
(Goldin & Gross, 2010)	MBSR	Common MMP exercises	8 weeks	8 weekly 2.5 h meetings plus one half-day meditation retreat.	Breath focused attention vs. distraction	Reacting to experimenter-selected social anxiety-related negative self-beliefs
(Zeidan et al., 2011)	Breath focus	Focus on the changing sensations of the breath (nostrils or abdomen)	4 days	4 daily 20 min sessions	Focusing on the changing sensations of the breath vs. rest	Neutral vs. noxious thermal stimuli
Cross-sectional studies						
(Gard et al., 2011)	Vipassana	Not well specified. However, references are given suggesting common MMP exercises	N.A.	N.A.	Mindfulness meditation vs. rest	Neutral vs. noxious thermal stimuli
(Grant et al., 2011)	Zen	N.S.	N.A.	N.A.	Resting state	Neutral vs. noxious thermal stimuli
(Taylor et al., 2011)	Zen	Common MMP	N.A.	N.A.	Mindful awareness of the breath vs. rest	Observing emotionally positive, negative and neutral pictures
(Westbrook et al., 2011)	BMI	Active focus on one's own thoughts, feelings and bodily sensations to pictures, while maintaining a nonjudgmental attitude toward those responses	1 day	N.A.	Mindfully attending vs. simply looking	Looking smoking-related and neutral images

processing similar to that state, even during rest. There is not yet empirical evidence, however, to support such a claim.

To partially overcome the limitation of the previous study, a following study investigated the neural correlates of 17 long-term Vipassana meditators in comparison with those of 17 matched non-meditators (Gard et al., 2011). In this study, the authors employed transcutaneous electrical stimuli generated with a custom-made impulse generator (833 Hz) applied to the left forearm (Gard et al., 2011). The stimulus intensity was adjusted for each participant individually to a self-reported moderate intensity level. Stimulus intensity, unpleasantness, and anticipatory anxiety were rated with visual rating scales. During the mindfulness condition, subjects "were asked to bring their attention to the skin surface underneath the electrode on their forearm and to observe the sensations related to the stimuli, making sure to be mindful, accepting, and being aware of the transient nature of the stimuli. During the baseline condition, participants were instructed not to employ any specific strategy" (Gard et al., 2011, p.3). Of note, the description of mindfulness employed by these authors is more similar to focused attention than to open monitoring, as attention is directed to a specific body area (Lutz, Slagter, Dunne, & Davidson, 2008).

Mindfulness practitioners, but not controls, were able to reduce pain unpleasantness by 22% and anticipatory anxiety by 29% during the mindful state. The contrast mindfulness vs. baseline for mindfulness practitioners vs. controls revealed a significant interaction in right posterior insula extending to secondary somatosensory cortex. This interaction was driven by increased activation of these areas in mindfulness practitioners but not in controls. Furthermore, activation (mindfulness vs. baseline) in this cluster was negatively correlated with a decrease in pain unpleasantness in mindfulness practitioners. On the other hand, a positive correlation between the same cluster and a decrease in pain unpleasantness was observed in controls. Also, the group × condition interaction examined with the contrast mindfulness vs. baseline for controls vs. mindfulness practitioners further revealed significant effects in the right and left middle frontal gyri and lateral PFC (lPFC). More in detail, the interaction in the right lPFC was driven by decreased activation in mindfulness practitioners and increased activation in controls in the mindfulness compared with the baseline condition. Finally, during anticipation of pain, the contrast mindfulness vs. baseline for mindfulness practitioners vs. controls revealed increased activation of rostral ACC (rACC) during mindfulness in mindfulness practitioners and no change in controls.

The results of this study provide further support to the bottom–up emotion regulation associated with mindfulness practice. In particular, these findings are consistent with the notion that, by activating schemata of objective sensory aspects of stimuli, largely mediated by the insula, (Craig, 2009), subjective emotional evaluative schemata, as well as the "distress" associated with these schemata, are significantly dampened (Leventhal, 1979). Finally, the activation of the rACC during the anticipation of pain might be explained by the role of this area in the processing of distracting events (Hölzel et al., 2007) or, alternatively, by its involvement in the anticipation of lower pain. However, in the absence of empirical investigation specifically dealing with this topic, these hypotheses remains speculative so far. Note, also, that the results of the present study should be considered against the limitations related to its cross-sectional design mentioned above.

In the last study employing a cross-sectional design, Taylor et al. (2011) compared the neural correlates of 12 experienced Zen meditators with more than 1000 h training with those of 10 novice meditators who were provided with instructions as to how to practice mindfulness meditation based on books and audio-recordings (e.g. Kabat-Zinn, 1994; Nhat Han, 1999). Novice meditators were also instructed to practice mindfulness meditation 20 min per day, for 7 days before the fMRI experiment. The stimuli consisted of a total of 216 pictures selected from the International Affective Picture System (Lang et al., 1997) balanced for valence and arousal rating across the baseline (simple rest)

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and the mindful (described in this study as "focused attention to the breath") conditions. The baseline and mindful conditions alternated between runs, but the order in which the conditions were completed was counterbalanced across participants.

The results of this study suggest that mindfully attending to positive and negative pictures could be associated with a bottom–up emotion regulation strategy in long-term meditators and with a top–down emotion regulation strategy in novice practitioners. The results observed in novice meditators are, therefore, presented in the next section. Overall, negative and positive pictures were rated as more emotionally intense than neutral pictures. Furthermore, pictures viewed in the mindfulness condition were rated as less emotionally intense than those viewed in the baseline condition. No between-group differences were observed for the contrast of neutral vs. negative pictures in expert vs. novice meditators during the rest condition. Furthermore, the only between-group difference for the contrast of neutral vs. positive pictures involved greater activation in the rostro-ventral ACC for beginner relative to experienced meditators. During negative emotional processing for experienced meditators, but not for beginners, a trend towards significance for mindfulness-induced deactivation were observed in the left lPFC. With regard to positive emotional processing, no significant mindfulness-induced deactivation was observed in expert vs. novice meditators. Finally, when examining general effects induced by mindfulness, i.e. across valence categories, mindfulness-induced deactivation was found in the right mPFC and PCC for experienced meditators relative to beginners. A similar de-activation (involving only the mPFC) was also observed within the group of experienced meditators during mindfulness vs. rest condition.

Of note, the results of this study extend previous finding by showing that long-term mindfulness training might reduce activity in brain areas associated with self-referential processing of the DFM. A possible mechanism underlying this finding could involve higher acceptance of emotional states which, in turn, is thought to reduce self-referential rumination about these states (Buckner et al., 2008). Furthermore, no significant difference on emotional intensity was observed between experienced and beginner meditators. However, the neural correlates of the two groups were significantly different from one another (see also the next section). Therefore, the authors suggested that the positive effects of mindfulness might be mediated by different mechanisms in short- and long-term practitioners. In particular, long-term practitioners might have developed increased mental stability as compared with novice meditators. This claim is consistent with the notion that long-term meditators did not show differential amygdala activation while viewing emotionally salient vs. neutral clips. On the contrary, a significant increase of amygdala activation was observed in novice meditators during emotionally salient stimuli as compared with neutral stimuli that was dampened during the mindful condition.

Finally, a single uncontrolled prospective study investigated the effects of an 8-week MBSR program in a small sample of 16 patients (14 completers) suffering from social phobia (Goldin & Gross, 2010). This study built on the notion that social phobia is a psychological disorder characterized by emotional and attentional biases as well as by distorted negative self-beliefs (Goldin, Manber, Hakimi, Canli, & Gross, 2009; Mueller et al., 2009). Participants were presented with 18 experimenter-selected social anxiety-related negative self-beliefs that referred to self-focused, self-critical personal beliefs, such as "People always judge me". Each trial consisted of reacting to a negative self-belief for 12 s followed by an implementation of attention regulation based on a cue to either "Shift attention to the breath" (instructing to direct attention to the physical sensation of their own inhalation and exhalation) or a distraction-focused attention based on counting numbers presented in a pseudorandom sequence. Following the implementation of the attention regulation strategy, participants provided a negative emotion rating expressed on a 5-point Likert scale. Of note, the description of the mindfulness task employed by these authors is more similar to concentration than to mindfulness meditation, as defined by Lutz, Slagter, Dunne, and Davidson (2008).

The results of this study showed that no significant difference on emotional rating was observed in emotional rating from baseline to endpoint during distraction periods. However, a significant decrease of emotional intensity during the emotional task was observed at endpoint during breath focused-attention. Furthermore, following mindfulness training, increased activity in brain regions implicated in visual attention such as inferior and superior parietal lobule, cuneus, precuneus and middle occipital gyrus was observed during breath focused attention as well. Also, compared with pre-MBSR, at endpoint MBSR patients demonstrated a significant decrease of right amygdala response prior to the cue to shift attentional focus to breath sensation.

One way to interpret the result of this study is that MBSR may have helped adults with social phobia be more visually engaged in and, therefore, less avoidant of, negative self-beliefs. Furthermore, the decreased amygdala response during breath focused attention observed at endpoint might reflect an effortful attempt to implement breath-focused attention emotion regulation at baseline and a MBSR-related shift to a more automatic implementation of breath-focused attentional regulation even before being cued to do so. This study is limited by the lack of a control group aimed at controlling for the non specific effects of mindfulness practice, such as expectancy effect, to which subjects are randomly assigned. However, it provides some evidence to suggest a causal relationship between mindfulness training and reduced activation of limbic areas without concurrent recruitment of PFC areas.

In sum, the five studies mentioned above suggest that mindfulness training could be related to lower emotional reactivity to stimuli aimed at evoking emotion regulation strategies that is not meditated by enhanced top–down regulation of PFC areas upon limbic areas, such as the amygdala and the striatum. Furthermore, the functional connectivity between limbic and PFC areas usually observed in studies focusing on top–down emotion regulation strategies seem, in the case of mindfulness training, replaced by a different connectivity concerning areas involved with viscero-somatic awareness. Note, however, that several limitations including the lack of active comparison groups, the use of a cross-sectional design in the majority of studies as well as the frequent inappropriate definition of mindfulness (see the section "an integration of current evidence") suggest to consider these findings with caution.

7. Studies suggesting top–down regulation

Four studies have been published so far that preliminary suggest that mindfulness training could recruit areas of the PFC to regulate emotional brain areas. In this case, three studies employed a prospective design whereas a single study employed a cross-sectional design. Therefore, prospective studies will be reviewed first. In an early study, Farb et al. (2007) investigated the effects of a standard 8-week MBSR program on brain activity by means of a paradigm aimed at evoking self-referential processes. In this study, 36 subjects were randomized to MBSR or to a waiting list (WL) and prospectively followed for 8 weeks. At baseline, subjects were instructed to distinguish between an experiential and a narrative focus (Watkins & Teasdale, 2001). The experiential focus (EF), aimed at enhancing present-centered attention, was described as paying attention to "what is occurring in one's thoughts, feelings and body state, without purpose or goal, other than noticing how things are from one moment to the next" (Farb et al., 2007, pp. 314–315). This description is consistent with the definition of mindfulness reported above (Lutz, Slagter, Dunne, & Davidson, 2008). On the other hand, the narrative focus (NF) was described as "judging what is occurring, trying to figure out what that trait word means to the participant, whether it describes the participant, and allowing oneself to become caught up in a given train of thought" (Farb et al., 2007, p. 315). The task consisted in the observation of 8 sets of six personality-trait adjectives constructed from a list of personality-trait words each of which contained three mildly positive traits and three negative traits (Fossati et al., 2003).

At baseline, EF was associated with relative reductions in several discrete regions along the cortical midline brain areas characterizing the DFM and with a relative increase in left lateralized regions, including the dlPFC and the vlPFC as compared with the NF, possibly reflecting greater task-related executive control and attentional allocation. Following mindfulness training, EF was associated with pervasive deactivations of several areas of the mPFC as compared with the NF. Significantly reduced activity in the left dorsal amygdala was observed as well. Additionally, EF resulted in increased recruitment of a right lateralized cortical network, including the dlPFC and inferolateral PFC, insular cortex and secondary somatosensory cortex in subjects randomized to MBSR, but not in those randomized to the WL at endpoint. A functional connectivity analysis further revealed that in novices the activation of the insula showed a strong coupling with midline cortical regions such as right vmPFC. However, these activations were rendered uncorrelated in subjects who completed MBSR. This decoupling was replaced by an increased coupling of right insula with right dlPFC.

Consistently with a dual-mode hypothesis of self-awareness, the authors interpreted this finding as suggestive of a fundamental neural dissociation in modes of self-representation that support distinct, but usually integrated, aspects of self-reference: the higher order self-reference characterized by neural processes supporting awareness of a self that extends across time (related to left lPFC; e.g. Fossati et al., 2003; Kelley et al., 2002) and more basic momentary self-reference characterized by neural changes supporting awareness of the psychological present (related to right lPFC; Ruby & Decety, 2004). Note that this study does not explicitly lend support to the top–down regulation of PFC areas on limbic areas. Indeed, no functional connectivity was reported between lPFC areas and amygdala. However, the shift away from midline cortical structures and the amygdala toward more lateral PFC regions supports the possibilities that mindfulness training allows for the development of a more self-detached and objective analysis of interoceptive (insula) and exteroceptive (somatosensory cortex) sensory events rather than their affective or subjective self-referential value (Ruby & Decety, 2004). Alternatively, it could be hypothesized that this shift allows for a reappraisal of emotionally salient stimuli that leads to lower rumination and emotional reactivity (Farb et al., 2007).

Building on the notion that dysphoric reactions following reappraisal failure consistently explain why some individuals become overwhelmed by negative emotions, a subsequent study of the same authors (Farb et al., 2010) further qualified the role of the right lateralized network observed in their early study following MBSR. In this study (that employed the same design of the earlier one) a sadness provocation paradigm was employed, in which individuals randomized to either MBSR or WL were presented with neutral and sadness-evoking clips (see Farb et al., 2010 for further details). At the end of a 30-seconds reflection period following each clip, participants had to rate their level of sadness on a 5-point Likert scale.

In the WL group, sadness provocation activated a midline network associated with ruminative and self-reflective processing previously associated with the DFM (Buckner & Vincent, 2007; Gusnard et al., 2001) as well as left-sided areas including, among others, left dlPFC. Furthermore, significant deactivations associated with the view of sadness-evoking clips were observed in the right viscerosomatic cortices peaking in the right insula. On the other hand, the MBSR group showed significantly higher activation of several areas including right insula, right subgenual ACC and vlPFC during sadness provocation in comparison with the control group at endpoint. Further analyses revealed that regions of relatively increased activity in the MBSR group represented a recovery from the deactivations related to sadness found in controls. On the other hand, subjects randomized to MBSR showed decreased activation in posterior cortical midline structures, such as right precuneus, and right and left lPFC in comparison with controls. Subsequent analyses further revealed that the deactivations in the MBSR group represented a reduction of activations related to sadness.

Of note, higher self-reported depression scores following sadness induction, as measured with the Beck Depression Inventory II (Beck, Steer, & Brown, 1996), were negatively correlated with activation of the right insula and right lPFC and positively correlated with the left superior temporal sulcus (Wernicke's area). This finding could suggest an opponent relationship between left-sided language and right-sided interoceptive areas. On the other hand, no significant difference was observed on self-reported sadness between groups. This suggest that it is unlikely that the different neural patterns observed in the MBSR group are simply due to a blunting of emotional experience or impairment in affective processing (Farb et al., 2010).

Overall, the results of this study, including lower insula de-activation and higher engagement of right subgenual ACC and vlPFC in the MBSR group could be interpreted as suggestive of the development of metacognitive skills that could allow for a detached view of emotionally salient stimuli, implying some sort of regulation of emotional responses (Farb et al., 2010). Note, however, that this top–down regulation activity could be different from that classically related to cognitive reappraisal. Indeed, no involvement of the dlPFC, the brain area most frequently associated with active cognitive reappraisal (Ochsner & Gross, 2005; Wiech et al., 2006), was observed. Furthermore, no significant reduction in self-reported sadness was observed in the MBSR group as compared with the control group. This suggests that no attempt was done to manipulate the interpretation of sad clips in a way that could lead to a more positive reappraise. This explanation is also consistent with the reduced activity in the MBSR group of left language areas in comparison with the control group.

On the other hand, the lower insula de-activation in the MBSR group that was related to decreased depression scores provides further support to the notion that mindfulness training could allow for a more interoceptive way of relating to present moment experience that is associated with less cognitive elaboration such as rumination or expressive suppression (Craig, 2009; Ochsner & Gross, 2008). Of note, this study suggests that the top–down regulation and viscero-somatic (bottom–up) regulation hypotheses are not mutually exclusive. Rather, they could work synergistically to lead to the positive effects observed following mindfulness training. Note, however, that both studies were limited by the lack of an active control group that does not allow to understand the extent to which observed effects of mindfulness training on brain activity are specifically attributable to this training or to other non specific effects. In addition, they were also limited by the lack of follow-up measures. This, in turn, makes it impossible to understand whether the effects observed immediately following the MBSR program tend to change over time and are dependent on the continuation of meditation practice.

A further study explored the effects of a brief (4 sessions) 20-minutes mindfulness training on painful stimuli in a small sample of 18 (15 completers) novice meditators (Zeidan et al., 2011). In this study, subjects were instructed to focus their attention on the changing sensations of the breath occurring at the tips of their nostrils while noting the rise and fall of the chest and abdomen. This description differs from mindfulness intended as an open monitoring of the whole field of awareness and is more similar to a focused attention/concentrative practice (Lutz, Slagter, Dunne, & Davidson, 2008). During the third and fourth session an audio recording of MRI scanner sounds was introduced during the last 10 min of meditation to familiarize subjects with the sounds of the scanner. During the scan session subjects received a random sequence of neutral and noxious thermal stimuli delivered to the posterior part of the right calf. Subjects had to rate pain intensity and pain unpleasantness as well by means of a visual analogic scale.

Before meditation training, no significant difference was observed either in terms of pain ratings or in terms of neural activity for the

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comparison between attention to the breath and simple rest. Following the training, subjects reported significant decreases in pain intensity and pain unpleasantness while meditating. Furthermore, the neural correlates of meditation at endpoint included higher activations bilaterally in regions involved with interoceptive awareness, such as primary and secondary somatosensory regions and anterior insula. Also, they included activations in brain regions associated with the self regulation of pain, such as the ACC and OFC, as compared with attention to the breath at baseline. On the other hand, significant de-activations were observed in the PCC and in the mPFC. Additionally, in the presence of noxious thermal stimuli, meditation reduced pain-related activation of the controlateral primary somato-sensory cortex. Furthermore, individuals with the greatest reductions in pain intensity ratings exhibited the largest meditation-induced activation of the right anterior insula and bilateral ACC. Finally, individuals with the greatest reductions in pain unpleasantness ratings exhibited the greatest activation of the OFC and the greatest deactivation of the thalamus.

The OFC has been implicated in regulating affective responses by manipulating the contextual evaluation of sensory events (Rolls & Grabenhorst, 2008) and processing reward value in the cognitive modulation of pain (Petrovic & Ingvar, 2002). Accordingly, the authors suggested that meditation-related OFC activation might reflect altered executive-level reappraisals to consciously process reward and hedonic experiences that, in turn, could reduce thalamic activity (Zeidan et al., 2011). Furthermore, the association between greater reductions in pain intensity ratings and higher activation of the right anterior insula and bilateral ACC is consistent with the notion that these regions play a major role in the evaluation of pain intensity and fine-tuning afferent processing in a context-relevant manner (Oshiro, Quevedo, McHaffie, Kraft, & Coghill, 2009; Starr et al., 2009). It should be noted, however, that the lack of a control group and of follow-up measures do not allow to exclude that observed changes are simply related to *task exposure effects* as well as to non specific effects of training, or that they tend to disappear briefly following the discontinuation of the training.

Finally, as reported above, Taylor et al. (2011) compared the neural correlates of 12 experienced Zen meditators with more than 1000 h training with those of 10 novice meditators while viewing affective pictures. Data about experienced meditators have been reported above. During negative and positive emotional processing, mindfulness-induced deactivations were observed for beginners relative to experienced meditators in bilateral amygdala. Also, for beginners, but not for experienced meditators, mindfulness induced activity in several brain areas including bilateral frontal gyri and right PCC across all valence categories. Finally, when examining group difference across conditions and valence categories, novice meditators exhibited increased activity in many areas including left OFC and thalamus. Overall, these findings are consistent with the hypothesis that for beginners relative to experienced meditators the effects of mindfulness training could be mediated by a top–down regulation of some PFC areas on the amygdala during negative and positive emotional processing. As this study employs a cross-sectional design, however, there is no possibility to infer causality about the observed effects of training. Furthermore, it does not allow to determine whether novice meditator actually differ from long-term practitioners in terms of, for instance, motivation, temperamental predisposition and further lifestyle variables.

In sum, the four studies reviewed in this section provide some evidence to suggest that short-term mindfulness training could be related to alterations to top–down processing. These alterations might, in turn, account for the beneficial effects of mindfulness practices. Note, however, that the dearth of information about functional connectivity between PFC and limbic areas limits the possibility to firmly establish the actual relationship existing between the activation of such areas in studies reviewed in this section. Furthermore, the several limitations mentioned above, including small sample size, lack of active comparison groups and the cross sectional design of the last study suggest that this finding should be considered with caution.

8. An integration of current evidence

The majority of studies reported in the previous two sections converge on suggesting the significant role of mindfulness training in the reduction of activation of cortical midline structures previously associated with the DFM, probably reflecting the reduction of self-referential processing associated with mindfulness practice. Furthermore, they strongly point to the increased activation of areas involved with somatic awareness, such as the insula, as a consequence of mindfulness training. However, they alternatively suggest that mindfulness training could be described as a bottom–up process characterized by reduced activation of limbic areas with no recruitment of PFC areas to regulate these emotional areas, or that it could be described as a top–down emotion regulation strategy characterized by the recruitment of PFC areas that, in turn, modulate limbic areas.

Of note, a large number of studies ranging from clinical to neuropsychological and neurobiological studies further support one of this view, making it difficult to draw definitive conclusion as to whether mindfulness training is better conceptualized as a top–down or as a bottom–up process. Supporting the bottom–up process underlying mindfulness training, van den Hurk et al. (2010) recently found that experienced meditators showed decreased intersensory facilitation, directly supporting the reduced reactivity account. Furthermore, a recent electroencephalography study found decreased frontal top–down control and increased sensory processing in mindfulness practitioners when they were being presented with oddball auditory stimuli during meditation (Cahn & Polich, 2009). Further studies provided evidence that mindfulness training could be associated with improvement in the attentional blink, reflecting a reduction in brain resource allocation that is independent from cognitive evaluative processes (Slagter et al., 2007; van Leeuwen, Muller, & Melloni, 2009).

On the other hand, supporting the top–down process underlying mindfulness training, Creswell, Way, Eisenberger, and Lieberman (2007) found that individuals high in dispositional mindfulness showed increased lPFC and decreased amygdala activity when explicitly instructed to label affective stimuli. Furthermore, Fresco, Segal, Buis, & Kennedy (2007) observed a modest but significant correlation between decentering, a psychological construct within cognitive psychology that shares strong resemblances with the concept of mindfulness, and positive reappraisal. Also, Garland et al. (2009) underscored that some studies supporting enhanced attentional processes following mindfulness training (Chambers, Lo, & Allen, 2008; Jha, Krompinger, & Baime, 2007) could likewise be interpreted as suggesting enhanced ability to positively reappraise events. Indeed, significant overlaps existing between PFC areas involved in these attentional processes and those involved in positive reappraisal. The possibility to draw definitive conclusions about each of these claims is further limited by the several methodological shortcomings mentioned above that make it difficult to understand the extent to which the observed neural effects associated with the cultivation of mindfulness are specifically attributable to mindfulness training or to other non specific factors such as repeated task exposure, expectancy effect, increased concentration and so forth. However, regardless of these methodological deficits, a close look to reviewed findings can allow for the formulation of some hypotheses and of some challenging questions that future research should more deeply investigate.

A first hypothesis of our review was that different neural correlates of mindfulness could vary as a function of the amount experience in mindfulness training. As an example, the neural correlates of long-term mindfulness practitioners (including practitioners with years of experience) could be significantly different from those of short term-mindfulness practitioners (including subjects addressed to brief mindfulness inductions or to common mindfulness based interventions such as MBSR). Of note, the results of reviewed studies provide partial evidence to support such claim. Indeed, a large number of shorter mindfulness trainings provides support for the top–down regulation account of mindfulness training (Farb et al., 2007, 2010; Taylor et al., 2011; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010), whereas all cross-sectional studies focusing on long-term meditators (Gard et al., 2011; Grant et al., 2010; Taylor et al., 2011) converge on supporting the reduced reactivity (bottom–up) account of mindfulness training.

Notable exceptions included the study by Westbrook et al. (2011) and the study by Goldin and Gross (2010). The former study suggested that in a sample of smokers wishing to quit smoking a brief properly defined mindfulness induction was associated with neural correlates supporting the bottom–up hypothesis of mindfulness process. The latter study suggested that, in a sample of patients suffering from social phobia, the neural correlates of MBSR could be better described as a bottom–up rather than as a top–down emotion regulation strategy. Note, however, that, while the former studies were specifically concerned with psychologically healthy subjects, the studies by Westbrook et al. (2011) and by Goldin and Gross (2010) investigated clinical samples of patients. Such a difference further raises the possibility that the neural correlates of mindfulness training could vary as a function of the psychopathological status of subjects under investigation. Note, however, that this hypothesis has not been verified by rigorous neuro-imaging studies including both psychologically healthy subjects and subjects with specific psychological disorders within the context of the same experimental design. Furthermore, in the present paper we considered subjects addressed to a brief mindfulness induction as well as those addressed to modern MBIs as short-term practitioners. On the other hand, we considered subjects with extensive practice (such as subjects with 1 or more years of meditation experience usually included in cross-sectional studies) as long- term practitioners. We wish to underscore, however, that such a dichotomy is more an artificial but useful classification rather than a clear and neat distinction.

Another hypothesis of our review was that different definitions of mindfulness might account for the discrepancies observed across different studies. On the basis of reviewed findings, however, it seems unlikely that different descriptions of mindfulness are consistently related to different neural correlates. Indeed, while some studies properly defining mindfulness as an open monitoring of the whole field of awareness have supported the bottom–up regulation hypothesis (Westbrook et al., 2011), other studies have supported the top–down regulation hypothesis (Farb et al., 2007, 2010). Similar observations can be extended to studies describing mindfulness as focused attention practice on a specific part of the body such as the breath. Note, however, that the possibility to disentangle mindfulness from concentration is not as easy as one would expect. Indeed, a strong relationship exists between these two practices and improvements in one meditation type are thought to implicitly influence improvement in the other type of meditation as well (Lutz, Dunne et al., 2008).

Alternatively, it could be hypothesized that the acceptant and non-judgmental attitude cultivated by both mindfulness and concentrative training rather than the open monitoring of the whole field of awareness cold be the most important mechanisms leading to specific changes in clinical outcomes and concurrent neural correlates (Hayes, Luoma, Bond, Masuda, & Lillis, 2006). In line with this hypothesis, Chiesa and Malinowski (2011) [illegible]ntly underscored that it is reasonable to ask whether the positive effects of mindfulness training are more properly attributable to participants' developing greater attentional control and/or to the change in their attitude characterized by letting go of (accepting) the habitual tendency to control or manipulate different aspects of their internal experience (Bishop et al., 2004). However, a careful look at the instructions provided in all included studies allows for the understanding that participants have been invited to accept ongoing experience as it was in all reviewed studies. Therefore, the instruction to accept current experience is unlikely to be a factor of heterogeneity across included studies.

Also, we suggested that different findings could be associated with different tasks employed to evoke some sort of emotional response and emotion regulation. However, as for the hypothesis mentioned above, studies employing different tasks (verbal stimuli vs. painful stimuli) alternatively suggested a top–down vs. a bottom–up process of mindfulness. Finally, a single study was specifically concerned with the investigation of a resting state in long-term mindfulness meditators as compared with matched controls (Grant et al., 2011). As a consequence, it is not possible to draw definitive conclusions about the extent to which such methodological difference could be associated with different findings.

Overall, the hypothesis that received the largest support from neuroimaging studies reviewed above is that short-term mindfulness meditation practitioners might achieve benefits from mindfulness training mainly by means of a top–down regulation of PFC areas on limbic areas whereas long-term mindfulness meditation practitioners might achieve benefits by means of bottom–up regulatory processes, at least among healthy subjects. Note, however that the top–down regulation observed in novice meditators could be linked with mechanisms different from cognitive reappraisal. They could include, as an example, the development of a more detached ability to observe thoughts, emotions and sensations with a concurrent reduction of self-referential processes associated with midline cortical structures of the DFM. On the other hand, long-term meditators might develop a more stable reduced reactivity to emotionally salient stimuli that does not involve the recruitment of cognitive evaluative PFC areas to dampen automatic emotional responses meditated by limbic areas. However, more rigorous prospective long-term randomized controlled studies are needed to confirm such a possibility.

Furthermore, in line with the concerns of several authors (Chiesa et al., 2011; Davidson, 2010; Williams, 2010), one should not forget the possibility that even subtle differences in meditation instructions employed by different teachers and traditions could be related to significantly different neurobiological findings. As an example, traditional authors frequently describe mindfulness as a means to overcome human suffering related to an erroneous concept of the self and of reality, that, in this process, are seen as an ever-changing flow of psychophysical phenomena void of any lasting self (Nydahl, 2008). Therefore, according to this view, there is no need to reappraise events in a less harmful way, and the possibility to observe neural correlates of reduced reactivity is increased. On the other hand, according to some modern mindfulness instructors, mindfulness could be best described as a practice specifically aimed at reappraise negative events in a more adaptive way (e.g. Garland et al., 2009 and Gilpin, 2009). In this case, it could be more likely to observe neural findings suggesting a top–down mechanisms of mindfulness training. Future studies should therefore include information about the context and the attitude within which mindfulness is presented in each study.

9. Clinical implications

Although reviewed findings should be considered as preliminary, on account of the several limitations discussed above, they could have important clinical implications. First of all, our findings, in association with clinical findings suggesting the beneficial effects of MBIs (Keng et al., 2011), support the notion that mindfulness training could lead to these benefits, at least in part, by means of processes distinct from cognitive reappraisal. This issue is particularly important if one considers that, during both experimentally induced and clinically relevant depression and anxiety, a significant impairment of brain areas related to cognitive reappraisal is frequently observed (Keightley et al., 2003; Liotti et al., 2000, 2002). This provides an explanation as to why significant efforts to regulate negative emotions is observed in these patients without commensurate relief (Keightley et al., 2003; Liotti et al., 2000, 2002). As a consequence, the possibility to relate to unpleasant

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emotions by means of neural mechanisms other than cognitive reappraisal could be significantly helpful for patients with an impairment of brain areas associated with successful cognitive reappraisal.

Of note, preliminary findings from studies in subjects with social phobia (Goldin & Gross, 2010) and in subjects wishing to quit smoking (Westbrook et al., 2011) suggest that even a short-term mindfulness training could elicit a bottom–up process in clinical samples. In addition, more information about specific instructions provided by mindfulness teachers could further help distinguish between the invitation towards non-judgmental observation of events and some sort of invitation towards cognitive reappraisal of events. This, in turn, would help clarify whether these instructions facilitate an approach to unpleasant emotion that is different from more "traditional" cognitive reappraisal.

Of course, the facilitation of this bottom–up process should not be regarded as antithetical to the top–down mechanisms observed in other studies. Rather, these processes could be either described as lying on a continuum between two poles or, alternatively, as complementary processes which relative higher dominance depends on the stage of meditation practice, on mindfulness teacher's instructions and on the clinical status of subjects. For example, on the basis of our preliminary findings it could be hypothesized that mindfulness practitioners gradually shift from a larger use of top–down mechanisms of emotion regulation during early stages of practice to a larger use of bottom–up mechanisms of emotion regulation during later stages of practice. However, both bottom–up and top–down emotion regulation strategies could reasonably co-exist in most stages of mindfulness practice. As an example, a reduction of an unpleasant emotion could be achieved by means of the concurrent ability to reappraise such an emotion in a more adaptive manner and the ability to observe it in a more detached manner, being the former ability particularly employed by short-term mindfulness practitioners and the latter one particularly employed by long-term practitioners. However, rigorous empirical evidence is needed before more definitive conclusions could be drawn. Furthermore, as previously underscored, the influence of other variables, such as specific teacher's instructions, might likewise be worth of investigation.

Also, our findings preliminary suggest that even short-term mindfulness training is associated with significant alterations of brain patterns that, in the long-term, might lead to robust structural changes. This might explain why long-term meditators frequently report increased mental stability rather than continuous need to regulate their own mental processes (Lutz, Dunne, et al., 2008). Of note, this claim is supported by recent findings suggesting that long-term mindfulness meditation (Hölzel et al., 2008; Lazar et al., 2005) and sometimes even short-term mindfulness training (Holzel et al., 2010) are associated with significant alterations in brain structures involved with attentional and emotion-generative processes as well.

Finally, an increased awareness of body's responses and sensations to an emotional stimulus (supported by increased involvement of such areas as the insula, ACC and primary and secondary somatosensory cortices) might lead to greater awareness of one's emotions (Bechara & Naqvi, 2004; Damasio, 1999). This, in turn, is a precondition for being able to regulate those emotions. Therefore, our findings provide further support to the notion that mindfulness training could significantly help patients reporting a lack of awareness of internal experience such as those suffering from borderline personality disorder (Linehan, 1993), eating disorders (Hill, Craighead, & Safer, 2011) and substance abuse disorders (Schuman-Olivier, Albanese, Carlini, & Shaffer, 2011). Note, also, that increased awareness of one's own body responses and sensation has been associated with increased empathy (Lutz, Brefczynski-Lewis, Johnstone, & Davidson, 2008), a critical quality for such workers as health care professionals (Shapiro, Schwartz, & Bonner, 1998).

10. Limitations of current research and suggestions for future studies

As reported above, reviewed studies suffer from several methodological shortcomings that limit the possibility to generalize observed findings and to draw definitive conclusions. Major limitation of reviewed studies include: 1) small sample size, which reduces the generalizability of observed findings to subjects other than those under investigation in the study; 2) the lack of control groups, that does not allow to exclude that pre-post findings are simply related to task or neuro-imaging device exposure effects; 3) the use of a waiting list as a comparator that does not allow to distinguish between the specific and the non specific effects of mindfulness training, such as positive expectancy and motivation; 4) the main use of non clinical samples that limits the possibility to generalize reviewed findings to specific populations of patients suffering from psychological disorders; 5) the lack of randomization that raises concerns that possible non investigated differences between groups rather than mindfulness training are actually responsible for observed differences; 6) the impossibility to blind subjects to the specific technique under investigation; 7) the lack of information about behavioral data in meditators and controls, that limits the possibility to understand whether possible confounding factors such as anxiety levels during the scan sessions might exist; 8) the use of a cross-sectional design in studies dealing with long-term mindfulness practitioners, that does not allow to infer causality as to whether observed differences between meditators and controls are actually the result of mindfulness training or of pre-existing baseline characteristics between subjects more prone to meditate; 9) the lack of information as to whether study participants actually perceive they were in the mindfulness state or not and, most importantly; 10) the use of different definitions and practices of mindfulness.

Therefore, future studies could be improved by the following methodological recommendations. First of all, on the basis of preliminary findings in small samples, future studies should focus on larger samples that would allow for a higher possibility to generalize observed findings beyond subjects included in the study. Second, future studies should include one or, possibly, more control groups. In particular, they could include a waiting list control group that would allow to understand to what extent possible differences between baseline and endpoint findings are simply due to task or neuro-imaging device exposure effects. Furthermore, they should include an active comparator, such as simple stretching or relaxation training, that would account for some of the non specific effects of mindfulness training, such as expectancy effect and movement exercises included in some mindfulness protocols, while excluding the "active ingredient" of mindfulness practice (Slagter, Davidson, & Lutz, 2011). Ideally, subjects should also be randomized to different conditions so as to reduce possible undetected differences between groups. Furthermore, study protocols should not be described as specifically aimed at investigating mindfulness practice, but as aimed at comparing different emotion regulation strategies. In this way, the positive expectancy bias towards mindfulness practice could be reduced. The use of different comparators aimed at matching as much as possible the non specific effects of mindfulness training while excluding the claimed active ingredient of mindfulness, namely the non-judgmental open monitoring of the whole field of awareness, might further allow to reduce possible biases deriving from the impossibility to blind subjects to the specific condition they are addressed to.

Future studies could further benefit from the inclusion of healthy and clinical populations of subjects within the context of a single experimental design. This would allow for a better understanding of whether neural differences between psychologically healthy subjects and those suffering from psychological disorders might exist, while excluding systematic methodological differences across the studies. In line with this issue, more research is needed to explore the neural correlates of subjects suffering from psychological disorders. Indeed,

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the majority of current studies focused on healthy subjects. Also, possible confounding behavioral measures such as anxiety levels during or immediately prior to the scan and heart-rate or skin-conductance levels in response to specific experimental manipulations should be more deeply considered (Frewen, Dozois, & Lanius, 2008). In particular, these data could be incorporated as regressors of activity in brain regions of interest, as appropriate to the research questions of interest. Incorporation of this individual variability in one's modeling of neural responses might account for a greater amount of variance in the neuro-imaging signal measured in comparison with statistical models that solely attribute variability in neural processing to group-level or task-indexed differences (Frewen et al., 2008; Phan, Wager, Taylor, & Liberzon, 2002; Phan et al., 2003).

Additionally, because a random approach is not feasible for studies investigating very long-term meditators, a possible approach to overcome this issue could be to match meditators and non meditator controls not only for above-mentioned variables such as age, gender and education level but, more importantly, also for personality differences and interest towards mindfulness meditation (for a more in-depth discussion see Slagter et al., 2011). Also, more effort should be directed to rely on more commonly shared definition of mindfulness. It would be useful to investigate the neural correlates of different techniques such as focused attention to the breath or open monitoring of the whole field of awareness in subjects expert in both these approaches (e.g. Manna et al., 2010). Furthermore, as the neuro-phenomenology approach developed by Varela and colleagues suggests (Lutz & Thompson, 2003; Varela, 1996), it could be useful to combine quantitative measures of neural activity with first-person data about the subject's inner experience. This approach actively involves the participant in generating and describing specific and stable experiential or phenomenal categories. These reports could be useful in identifying variability in the response of the brain from moment to moment, and this unique information might guide the detection and interpretation of neural processes.

In addition, different emotions and emotion regulations' evoking stimuli including painful and reading affective words might be implemented within the context of the same experimental design. This could allow to investigate the possibility that the neural correlates of mindfulness training during emotion regulation are independent from the specific task employed. Of note, a recent review has suggested that implementing the majority of the methodological issues mentioned above can be and has already been successfully applied to clinical studies focusing on MBIs (Chiesa, 2011). Finally, the investigation of the effects of different teacher's instructions and the inclusion of meditators at different stages of meditation practice could allow for a more detailed investigation of whether the bottom–up and the top–down mechanisms of action of mindfulness training are not mutually exclusive but depend on some of these variables.

11. Conclusion

In spite of the consistent methodological shortcomings and some discrepancies between experimental paradigms, definitions of mindfulness and experience levels of meditators, reviewed findings preliminary suggest that in healthy subjects mindfulness training could be associated with top–down emotion regulation in short-term practitioners and with bottom–up emotion regulation in long-term practitioners. Alternatively, both processes could be more or less associated with mindfulness training depending on the emphasis given by specific instructors and traditions. Future studies should implement several methodological issues to improve current understanding of the neural correlates of mindfulness training and to allow for a better understanding of the factors that influence the neural correlates of mindfulness in the direction of a top–down or of a bottom–up emotion regulation strategy.

12. Uncited reference Q3

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