Neural Correlates of Focused Attention and Open Monitoring Meditation

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Abstract

Meditation, used initially as a vehicle for self-discovery and attainment of enlightenment, is today a tool for well-being among the general public and has even found its way into the clinical milieu. Meditation is challenging term to define and the variety of meditation practices, all with their own aims, pose a problem in terms of scientific understanding. A better sense of how these practices compare will help both general public and neuroscientists. Here, two of the fundamental practices originating from Buddhist tradition, focused attention (FA) and open monitoring (OM) meditation are compared. FA meditation activates mainly right medial/lateral PFC, parts of the limbic system and ACC. These regions help with sustaining attention and monitoring goal-conflicting distractors. FA deactivates parts of the default mode network (DMN), responsible for non-task specific processes and mind wandering. OM meditation reduces pain by top-down regulation of the limbic system. OM engages left fronto-parietal and insular regions, which help with conscious access of thoughts and emotions. OM seems to affect parts of the DMN. The thalamus is involved in both practices, where it helps to relay sensory signals in accordance with the different aims of each practice. This thesis hopes to contribute to a better understanding of how two main categories of meditation compare concerning their neural correlates.

*Keywords*: meditation, focused attention, open monitoring, mindfulness, activations, deactivations
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Introduction

Meditation, with its origin in Eastern traditions, has been practiced in the context of healing and spirituality for nearly 5,000 years. Historically, meditation is used as a self-regulatory practice of the body and mind, which not only enhances attention and enriches emotional well-being but to fundamentally liberate from the concept of a separate ego, as Buddha realized some 2,500 years ago. Today, meditation is more understood as an umbrella term for complex attentional and emotional regulation strategies developed for different purposes (Fell, Axmacher, & Haupt, 2010; Gundel et al., 2018). Contemporary research shows that meditation leads to improvements, ranging from better attention, memory, and immune function to prosocial behavior and clinical applications; it is used as a means to alleviate disorders, such as depression and anxiety (Fox et al., 2014). With such promising effects coming from ancient techniques, it is no surprise that meditation has gained popularity in the public domain, where many use it as a tool for sustaining wellbeing (Muehsam et al., 2017).

In a nationwide investigation carried out in the United States in 2012, 18 million adult Americans—equivalent to 8% of the US adult population—stated that they practiced some type of meditation; this figure is likely to be even higher today (Clarke, Black, Stussman, Barnes, & Nahin, 2015).

Ancient traditional texts describe and relate meditation with cultivation, contemplation, or familiarization, thus making meditation somewhat ambiguous to define (Chiesa & Malinowski, 2011). Regardless of definition, it is clear that today, there is a diversity of meditation practices, each with its own aim and routine. However, increasing popularity and inconsistencies in definition, along with the vast number of practices pose a problem for practitioners and scientists alike (Brewer et al., 2011), especially since an arguably simple practice demonstrates a variety of benefits. Meditation is studied in different scientific fields, such as in the field of psychology and psychopathology. Modern neuroscience provides yet another tool of gathering evidence in favor for the construct of meditation. Therefore, a better understanding of how meditation practices compare and differ in terms of their neural function, is of significance to both the general population who use such techniques in their daily lives and the scientific community (Ainsworth, Eddershaw, Meron, Baldwin, & Garner, 2013; Fox et al., 2014). If meditation techniques are to serve as a tool by which the development of body and mind is achieved, then the differences among various practices have to be firmly established as this allows better understanding and application.
The purpose of this thesis is to summarize the current evidence on meditation and provide an overview of the differences and similarities between various practices, originating from the Buddhist tradition. To achieve this aim, four general categories of meditation will be presented individually, along with their respective aims and ways of practice. However, the primary focus is narrowed down to two practices derived from Buddhist tradition: namely, focused attention meditation and open monitoring meditation. The reason is that those are the two main categories which have not yet been sufficiently investigated in terms of their similarities and differences. Although there have been many studies conducted on these two categories, there has been a noted dearth of studies directly comparing them. I hope this thesis to be a first step toward addressing that limitation. This thesis is organized as follows: first, a brief description of meditation and its origins is presented. Second, four general categories of meditation are discussed. Third, the functional neuroanatomy of focused attention meditation is explained by demonstrating activations and deactivations related to the practice; the same is later presented for open monitoring meditation. In this thesis, activations refer to increased neural activity as compared to baseline brain activity. Deactivation refers to decreased neural activity as compared to baseline brain activity. Functional magnetic resonance imaging and electroencephalography studies done on both categories will be presented. Finally, the central findings of both meditation types are evaluated, followed by an overview of research limitations, and indications regarding future directions.

**Meditation and Its Origins**

Meditation as a form of mental training has been practiced for the purpose of spirituality and healing for millennia; where it is normally contextualized in spiritual traditions. Although not bound exclusively to any specific spiritual tradition, the practice of meditation itself is mostly identified with eastern traditions, such as Taoism, Hinduism, and Buddhism (Chiesa & Malinowski, 2011; Fell et al., 2010; Khalsa et al., 2008). The latter’s teachings on meditation are based on Buddha’s discourse on the true nature of the world, the self, and the alleviation from suffering due to an incorrect understanding of reality (Chiesa & Malinowski, 2011). Buddha’s teachings on how to overcome life’s inherent challenges like sadness, pain, and suffering by attaining a state of enlightenment known as Nirvana eventually spread his teachings in Asia in two directions. One teaching reached far east and became known as the Mahayana tradition, whereas the other established itself in Southeast Asia and became known as Theravada tradition (De Benedittis, 2015), which to this date is still most dominant in India, Sri Lanka, and other Southeast Asian countries (Lee et al., 2012).
Early Theravada Buddhist texts describe two fundamental practices of meditation: one of which is called *Samatha* or *Samadhi* that refers to a calm state of mind with deep concentration and the other is known as *Vipasyana* or *Vipassana* that means insight; it has become more known in the West as mindfulness meditation (De Benedittis, 2015; Quaglia, Brown, Lindsay, Creswell, & Goodman, 2015). Buddhist *Vipassana* meditation has laid the foundation for today’s mindfulness practices, such as the broadly adapted eight-week mindfulness-based stress reduction (MBSR) program (Cahn, Delorme, & Polich, 2010). It is through the combination of both *Samatha* and *Vipassana* practices that the practitioner gains insight into the nature of things, such as suffering, impermanence, and identity (De Benedittis, 2015; Quaglia, et al., 2015). Thus, meditation can be seen as a vehicle towards liberation from an identification with the concept of an individual ego, which when realized leads to psychological happiness and well-being (Chiesa & Malinowski, 2011).

However, the interpretation becomes more complicated when one takes into account the different traditions that use words describing meditation. In the Yoga Sutras, which are ancient Hindu texts, meditation is the undertaking of inward contemplation; it is the in-between state concerning attention to an object and total absorption within it (Chiesa & Malinowski, 2011). Furthermore, Chiesa and Malinowski describe how the Pali and Sanskrit term *bhavana* translates into “cultivation” rather than reflection and contemplation, whereas in the Tibetan tradition the equivalent *sgom* (pronounced “gom”) is translated as “getting used to” or “familiarizing oneself” and not as contemplation. Considering how complex, diverse, and broad the terminology of meditation is, it becomes evident that capturing the full spectrum of meaning with one simple definition is rather difficult (Chiesa & Malinowski, 2011).

Nonetheless, compared to other contemplative practices, Buddhist traditions are well suited for understanding the theoretical model of meditation in a neuroscientific context due to extensive and precise descriptions as well as detailed theories about their practice (Lutz, Dunne, & Davidson, 2007). Regardless of different translations and numerous traditions that revolve around the practice of meditation, the field of research has been limited by the lack of a clear operational definition of meditation. According to Lutz, Slagter, Dunne, and Davidson (2008), failure to distinguish different types of meditation can be analogous to using the word “sport” for all sports activities as if they were virtually identical. Admittedly, for both meditation and sports, the actual results vary depending on what is truly done (Goleman & Davidson, 2017).
Currently, meditation encompasses complex attentional and emotional regulation strategies that are used for different ends, such as improving concentration and emotional balance, cultivating well-being, establishing calmness, relieving stress, relaxing the mind, alleviating depression, and reducing anxieties (Fell et al., 2010; Gundel et al., 2018; Lutz, Slagter, Dunne, & Davidson, 2008). Lutz et al. state that meditation is for the most part practiced in a formal, seated position with a straight spine, while the rest of the body is neither too relaxed nor too tense; other types of meditation, such as walking meditation, also exist (Hölzel et al., 2011).

Amid many definitions of meditation and numerous variations of the practice itself, Fell et al. (2010) emphasize the fundamental need for categorization. Lutz et al. (2008) propose a useful theoretical framework based on neuroscientific conceptions and traditional Buddhist meditation texts, where meditation, depending on how the attention is directed, has been grouped into two broad categories: focused attention (FA) and open monitoring (OM) meditation. But, based on differences in EEG band recordings, Travis and Shear (2010) propose to extend the categorization of FA and OM initially suggested by Lutz by adding a third category of meditation: mantra recitation. As research on meditation continues, more distinctions have been identified. Today, meditation can be divided into even more major categories, such as loving kindness meditation where feelings of joy and kindness are directed towards self and others, and compassion meditation, where the aim is to cultivate an attitude of compassion in relation to suffering. Due to the scarcity of data relating to other forms of meditation, such as visualization meditation, where the aim is the creation and sustention of visual images, including godly idols, mandalas and other geometric patterns; pratyahara, which aims at the purposeful separation from sensory inputs; and non-dual awareness meditation, which entails dissolving object and subject barrier, this review paper does not investigate such practices any further (Fox et al., 2016).

Several years after the Lutz et al.’s initial proposition, Fox et al. (2016) suggest organizing the literature on meditation into at least four different categories: focused attention, mantra recitation, open monitoring, and loving-kindness and compassion. However, these four categories are not definite; they are merely an early step in illustrating the relationship between different practices and neuroscientific research. As science on meditation advances, it is likely that further categorizations are developed. The four categorizations suggested by Fox et al. are discussed in more detail in later sections.

Normally, the two broad categories of FA and OM are mixed together, either over the entire course of a practitioner’s training or within a single meditation session (Lutz et al.,
Regardless of whether the attention is directed in a small, focused manner or a broader and open way, Cahn and Polich (2006) argue that most meditative techniques are found on a continuum between these two general categories. Boccia, Piccardi, and Guariglia (2015) state that in most meditation practices, both styles complement each other. Regardless of meditation style, some common goals are apparent, such as relaxation, attention regulation, and the ability to disengage from one’s own thoughts. The shared experience of many meditative practices consists of a metacognitive change in the relationship between feelings and thought; instead of occupying a person’s full attention, they are seen as an occurring and passing phenomenon (Cahn & Polich, 2006). Thus, being able to direct one’s attention purposefully is of great value in guiding behavior towards particular goals. The area of selective attention in relation to meditation practice has been heavily studied in the field of neuroscience and psychology (Lutz et al., 2008), but it is beyond the scope of this review.

Many contemplative practices, especially Buddhist meditation practices; such as Zen, Vipassana, and Tibetan, have their roots in Buddhist philosophy and are essentially centered around the development of Sati or mindfulness (Chiesa & Malinowski, 2011). Since the notion of mindfulness is a central element of Buddhist meditation and is inherent across various meditation practices, such as FA and OM (Cahn & Polich, 2006; Lutz et al., 2008; Scheibner, Bogler, Gleich, Haynes, & Bermpohl, 2017), it is necessary to explain the concept in more detail.

As previously mentioned, certain Buddhist meditative practices are deeply connected with the conceptual and historical origins of mindfulness. However, since many different Buddhist traditions have evolved over centuries, it is hard to find a single, clear, and uniform definition of mindfulness. Each definition has its roots in specific traditions, and should thus be understood within that context (Quaglia, et al., 2015). The lack of general agreement poses no limit to researchers in terms of operationally defining the concept. Marchand (2014) states that mindfulness pertains to particular qualities of attention and awareness that can be cultivated and developed through meditation; mindfulness is the momentary awareness of arising thoughts, emotions, and sensations in a detached manner. One of the most cited and modern definitions of mindfulness is that of John-Kabat-Zinn (2003), a researcher and the founder of mindfulness-based stress reduction program (MBSR), which is derived from the practice of traditional mediation and mindfulness. Kabat-Zinn defines mindfulness as “the awareness that emerges through paying attention on purpose, in the present moment, and nonjudgmentally to the unfolding of experience moment by moment” (p. 145).
Both meditation and psychological interventions based on mindfulness are used in various applications. Hölzel et al. (2011) state that mindfulness meditation is composed of three elements, which are closely connected to create a process of enhanced self-regulation: improved attention control, improved emotional regulation, and modified self-awareness (i.e., improved awareness of the body and decreased self-referential processing). Today, traditions such as Zen and Vipassana, are commonly known as mindfulness-based methods. Contemporary clinical meditation routines, such as the dialectical behavior therapy (DBT), mindfulness-based cognitive therapy (MBCT), and the previously mentioned MBSR are derived from these ancient meditation traditions (Chiesa & Malinowski, 2011; Kabat-Zinn, 2003; Scheibner et al., 2017).

Overall, this thesis clarifies the history of meditation and describes the two fundamental styles of meditation practice, which when practiced in combination can lead to liberation from ego and insight into the true nature of reality, leading to happiness and well-being. The thesis clarifies the complexity of defining meditation and explains the current framework that is based on attention direction. Moreover, the thesis explores the concept of mindfulness and its contemporary clinical methods. The following sections expound on Fox et al.’s (2016) four general meditation classifications, particularly focusing on FA and OM, highlighting their nature and demonstrating their distinctiveness.

**Four General Meditation Categories**

**Focused Attention Meditation**

Of the meditation techniques mentioned previously, one of the most central and broadly studied technique is known as concentrative or FA meditation (Lee et al., 2012), which can be found for example in the Buddhist Samatha tradition (Cahn & Polich, 2006). Focused attention meditation is characterized by attempts to direct and maintain focus on a particular event or a selected object, such as the sensation of breathing or a candle flame (Ainsworth et al., 2013; Lippelt, Hommel, & Colzato, 2014; Scheibner et al., 2017), without giving in to distractions such as “mental chatter,” sleepiness, or mind wandering (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007; Lippelt et al., 2014). The Buddha himself once practiced a particular type of FA meditation called, Anapanasati, which refers to the focused attention that is directed to the sensation of air entering and exiting the nostrils (De Benedittis, 2015). Single objects of focus can be concrete, such as a specific part of the own body, or they can be abstract, such as a feeling or imagined picture (Fell et al., 2010). The purpose of these objects is to serve as an anchor point that is not to be contemplated on during the
process, but returned to, once focus is no longer present (Malinowski, 2013). Being able to purposefully direct one’s attention is of great value when attempting to guide behavior towards particular goals (Lutz et al., 2008).

Usually, FA meditation training is practiced with the ambition of attaining a clear, calm, and peaceful state where reduction with emotions and thoughts is slowly reduced, something which is achieved by narrowing the focus of attention (Brefczynski-Lewis et al., 2007; Lee et al., 2012). Newcomers to meditation normally start with FA meditation, and once they are familiar with the technique, they proceed to OM meditation styles (Lippelt et al., 2014). In practice, FA meditators are instructed as follows: They are first told to focus on an object, such as the sensation of breathing that occurs when air enters and exits the nostrils; thereafter if and when they recognize that their focus has switched from the original object, they are instructed to disengage from the distraction and return to the original object of focus (Lutz et al., 2008).

This ability to regulate one’s attention is a central aspect of many meditation methods (Manna et al., 2010). In the case of FA meditation, this involves the ability to direct and maintain attention to a particular object (e.g., the sensation associated with breathing), to detect distractions (e.g., thoughts), and to disengage from the source of distraction, by shifting focus back to the originally selected object (Lutz et al., 2008; Manna et al., 2010).

**Mantra Recitation Meditation**

One of the most recognized forms of mantra recitation is called Transcendental Meditation (TM), which came to the West from the Brahmanical or Vedic traditions of India (Lutz et al., 2007). At first glance, Transcendental Meditation seems to have a great deal in common with focused attention meditation in terms of aims, such as freedom from mind wandering, maintaining focus, and relaxation of the mind (Fox et al., 2016). However, upon further examination, mantra recitation differs in terms of the object of focus (Fox et al., 2016; Travis & Shear, 2010). In FA, the focus is placed on natural physical sensations arising in the body, like the sensation of breathing, or on external objects, such as a focal point in space (Lutz et al., 2008); in Transcendental Meditation, in contrast, practice revolves around the repetition of a Sanskrit sound (known as a mantra), either spoken quietly in one’s head or aloud. The clear difference lies in the voluntary verbal-motor production (Fox et al., 2016; Travis & Shear, 2010). The mantra is thought to eventually occupy awareness during meditative practice to such a degree as to become effortless. It is in part this effortlessness that distinguishes this technique from other concentrative practices (Cahn & Polich, 2006).
The practice of Transcendental Meditation is said to be simple, as it involves no control or contemplation, and emphasis lies on developing a “transcendental awareness”, in which no thoughts are present (Cahn & Polich, 2006). According to Travis (2014), this type of meditation is said to produce a state of pure consciousness, in which the subject experiences freedom from ever-changing mental content to such an extent that the dichotomy of subject and object is transcended, and all that remains is pure consciousness. This pure conscious state is also known as transcendental consciousness. It is said to occur randomly during Transcendental Meditation practice and can last from ten to forty seconds.

**Open Monitoring Meditation**

According to Lutz et al. (2008), OM meditation practice involves the observation of the content of experience as it occurs from moment to moment. This is done in a nonreactive manner, with the purpose of gaining familiarity with the nature of all arising sensations and cognitive and emotional patterns (Lutz et al., 2008; Malinowski, 2013). The aim of OM is the upkeep of attention in an open perceptive state, with no judgment of cognitive and sensory content, and with the inclusion of meta-awareness (i.e., the act of observing the ongoing thought process) (Cahn & Polich, 2006). Unlike in FA meditation, in which certain elements are evaluated for relevance and inhibited, in OM meditation, content is not tied to a specific goal, nor is any of it pushed aside: Every arising sensation, thought, or feeling is attended to in an equal manner. Because of the importance of internal and external body sensations, the interceptive and exteroceptive sensory inputs in general receive greater processing in OM meditation than in FA types of meditation (Fox et al., 2016). As previously described, mindfulness is understood as the awareness that arises through intentionally paying attention, without any judgment, to the to the experience happening in the moment (Lutz et al., 2008; Marchand, 2014). If mindfulness is practiced in a meditative setting, it is referred to as mindfulness meditation and is usually placed in the OM category (Travis, 2014).

**Loving Kindness and Compassion Meditation**

Loving kindness meditation shares a close relationship with compassion meditation, although they are not indistinguishable (Fox et al., 2016). Loving kindness meditation places an emphasis on benevolence, a universal love for all beings, and it makes no distinction between oneself and others. Compassion meditation on the other hand, takes this practice slightly further by encouraging practitioners to visualize suffering elements (psychological or physical) in themselves and others; it aims at developing an attitude of compassion and wish to alleviate suffering and pain (Fox et al., 2016; Lee et al., 2012).
Typically, a traditional loving kindness meditation practice instructs the practitioner to first generate feelings of unconditional love, benevolence, and joyfulness towards themselves (Fox et al., 2016), and to then extend this love to a good friend, followed by a neutral person, a difficult person, and all four of them evenly, before encompassing all sentient beings (Lee et al., 2012). Any negative feelings that might manifest during practice are to be replaced by positive ones, such as feelings of empathy or altruism (Lippelt et al., 2014). Loving kindness meditation and compassion meditation contain elements of both FA and OM (Vago & Silbersweig, 2012). The FA component comes from the single-pointed target of focus (i.e., a person or animal) that is receiving the loving kindness, as well as the cultivation of one kind of emotion to the exclusion of other types. When feelings of compassion are universal, without any object of focus whatsoever, they can be seen as a form of OM (Fox et al., 2016).

In this paper, emphasis is exclusively placed on practices tied to FA and OM styles of meditation, as these are the two categories that have been the least frequently compared and contrasted in research (Fox et al., 2016; Lutz et al., 2008; Travis & Shear, 2010). No further light is shed on the remaining two styles, mantra recitation and loving kindness meditation.

**Focused Attention Meditation**

Based on the fact that FA meditation produces a narrow focus of attention, Lutz et al. (2008) predicted that this form of meditation should affect the brain systems responsible for sustained attention (e.g., the thalamus and the right frontal and parietal areas), selective attention (e.g., the temporoparietal junction, the ventrolateral prefrontal cortex, the intraparietal sulcus, and frontal eye fields), and conflict monitoring (e.g., the dorsolateral prefrontal cortex and the dorsal anterior cingulate cortex).

**Functional Neuroanatomy of FA Meditation**

**Activations.** Manna et al. (2010) performed a two-by-two mixed design functional magnetic resonance imaging (fMRI) study on Theravada Buddhist monks. They measured brain activity during FA and OM meditation, and they compared it with the activity during the resting state of each technique and between expert monks and novice practitioners. An fMRI is designed to indicate neuronal activity by measuring the changes in blood flow via so-called BOLD-signal (blood-oxygen-level dependent) (Gazzaniga, Ivry, & Mangun, 2013). Manna et al. predicted that in contrast to OM and resting state, FA meditation stimulates and maintains the regions involved in selective attention, such as the intraparietal sulcus, the frontal eye fields, the temporal parietal junction, and the ventrolateral prefrontal cortex, as well as regions involved in sustained attention, such as the thalamus and the right frontal and parietal areas,
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and in regions related to conflict monitoring, such as the dorsolateral prefrontal cortex and the anterior cingulate cortex (Manna et al., 2010).

Participants in the study consisted of eight expert Theravada Buddhist monks with an average of 15,750 hours of meditation practice in both FA (Samatha) and OM (Vipassana) styles of meditation, as well as eight novice meditators who were instructed to practice each style of meditation prior to fMRI scanning, for 30 minutes each day over a 10-day period. All participants were instructed to practice FA and OM meditation with eyes closed for six-minutes blocks, separated by a three-minute non-meditative resting state in between each block. The entire procedure consisted of three FA blocks and three OM blocks, with a resting period at the beginning and at the end of each block (Manna et al., 2010).

The within-group results of expert monks in an FA meditation state compared to their resting state indicated enhanced activity in three medial frontal regions consisting of the right medial anterior prefrontal cortex and the bilateral dorsal anterior cingulate cortex. Together these three regions reveal a positive correlation, indicating that they interact as a single unit, and they are particularly prominent during FA meditation. In comparison to the FA novices, the between-group analysis of FA experts illustrates an enhanced activation bilaterally in the dorsal anterior cingulate cortex, along with activation in the right medial frontal gyrus. The bilateral activations in dorsal anterior cingulate cortex, are in line with the hypothesized participation of conflict-monitoring regions during FA meditation (Manna et al., 2010). The dorsal anterior cingulate cortex finding is further confirmed in another study on FA meditation, this time in relation to mind wandering, in which activation in dorsal anterior cingulate cortex is seen in participants just as they become aware that their mind has wandered away from the object of focus (Hasenkamp, Wilson-Mendenhall, Duncan, & Barsalou, 2012). Regarding the medial anterior prefrontal cortex and medial frontal gyrus, the plausible explanation put forth is that these regions are responsible for focused awareness. Although it had been hypothesized that there would be activations in regions responsible for selective and sustained attention, no such activations were observed (Manna et al., 2010).

An fMRI study conducted by Lee et al. (2012) attempted to determine how Anapanasati FA meditation (which is focused on breath sensation) affects the brain during continuous processing tasks, tasks measuring attentional aspects, and during emotion-processing task, which measure emotional processes. Both tasks compared expert meditators to novice meditators, both in a meditative and baseline state. This study was a matched control study focused on eleven male Chinese expert meditators from the Theravada Buddhist tradition between the ages of 39 and 68, with an average of approximately 5,000 hours of meditation

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each. The eleven control subjects were instructed to perform three 20-minute meditation sessions each day, over the course of seven days.

Lee et al. (2012) assumed that FA meditation experts would present enhanced BOLD signals in brain areas related to attention, including the inferior parietal lobule, the superior temporal gyrus, the cingulate cortex, the caudate, and lateral prefrontal cortex, as these areas have been linked to attention in the past (Pagnoni, Cekic, & Guo, 2008). To test this hypothesis, participants were scanned in an fMRI-scanner while performing a continuous processing task. They observed a black screen displaying a different number between zero and nine every second, for 50ms at a time. The participants were instructed to press a button every time the number zero appeared on the screen.

The results of this experiment reveal that the FA experts made fewer commission errors (responding in the absence of target stimuli) during meditation than novice meditators, 0.7% compared to 2.0%, indicating that they might be better at withholding reactions to non-target stimuli. The FA experts also made fewer omission errors (not responding in presence of target stimuli) during meditation, 2.4% compared to 13.8% by novice meditators, suggesting that extended FA meditation helps with alertness in tasks involving sustained attention (Lee et al., 2012).

In terms of neurological findings, the region of interest analysis on continuous processing tasks reveals two regions of activation in FA experts, namely the right middle temporal gyrus and the right precuneus (Lee et al., 2012). The middle temporal gyrus is part of the temporal cortex, a region previously linked to sustaining attention (Karnath, Ferber, & Himmelbach, 2001). Activation in the precuneus might aid experts in focusing on a task without being affected by the reduced familiarity of the continuous processing task, as seen in Goldstein et al. (2007). In this study, participants demonstrate less activation in the precuneus the more tasks they performed, suggesting that longer exposure/habituation may lead to decreased attentiveness (Goldstein et al., 2007).

For the emotional processing tasks, participants were instructed to observe twenty happy, twenty neutral, and twenty sad pictures (e.g. happy babies, random scenes and injured animals), with each stimulus being presented randomly for three seconds at a time. The images were kept separate by a white fixation cross. Lee et al. (2012) observed that FA experts presented stronger BOLD signal in the left anterior insula while viewing happy pictures in the state of meditation compared to baseline. The activation in the left insula confirms the findings of an earlier study conducted by Nielen et al. (2009), in which the amygdala and insula were linked to states of arousal and valence when observing emotional
images. This study tested the response to affective pictures from International Affective Picture System (IAPS) in 23 healthy females. The subjects observed four categories of pictures, namely high arousal positive, high arousal negative, low arousal positive, and low arousal negative while being scanned in an fMRI machine. The results reveal a bilateral activation in the amygdala for all categories except for high arousal positive, which demonstrated activation only in the left amygdala. The left anterior insula, meanwhile, was directly responsible for arousal in negative pictures.

Lee et al. (2012) found an unexpected negative correlation in FA experts between previously mentioned activity in the insula and the reported levels of arousal and valence. Specifically, FA experts had a larger BOLD signal in their insula, yet they rated lower on arousal and valence. This finding goes against previous research done by Nielen et al. (2009), who found a positive link between reported intensity of emotions and insular activity (Nielen et al., 2009). Lee et al. (2012) explain this negative correlation by suggesting that, unlike novices, who normally do not regulate their emotions while being affected by happy pictures, FA experts may attempt to suppress the emotions generated by such images as a means of reaching a state of stillness.

Lee et al. (2012) discovered another interesting finding in relation to viewing sad faces during the emotional processing tasks: Specifically, expert FA meditators were characterized by a stronger BOLD signal in the left superior frontal gyrus in both baseline and meditation states than the baseline state of novices. Novice meditators had increased activity in the right inferior frontal gyrus in meditation state as compared to their baseline (Lee et al., 2012). Hence, when both experts and novices were in a state of meditation, they likely engaged the superior frontal gyrus and the inferior frontal gyrus to a greater degree than novices did at baseline in order to stabilize emotional reactivity. In experts, the lower emotional reactivity might be due, at least in part, to the effects of long-term practice, despite the fact that FA meditation does not emphasize the management of emotions (Lee et al., 2012). Taken together with the findings of a later study conducted by Tomasino and Fabbro (2016), which found that parts of the right dorsolateral prefrontal cortex are activated as a result of FA meditation, these findings support the hypothesis of Lutz et al. (2008) that the dorsolateral prefrontal cortex plays a role in attention. Thus, the focus and emotional stability of FA meditators might be due to their decreased emotional reactivity (Lee et al., 2012; Lutz et al., 2008).

In a recent fMRI study, Tomasino and Fabbro (2016) predicted that changes in areas linked to the resting state-network, task-related efficiency, inhibitory control and attention
would be seen after eight weeks of FA meditation training. The authors scanned thirteen healthy subjects with no prior experience with meditation. These subjects were trained by an experienced meditator for thirty minutes each week, over a period of eight weeks in a mindfulness-oriented meditation training setting that takes inspiration from the Theravada Buddhist School of meditation and the standardized mindfulness-based stress reduction method. Training consisted of both theory and practice. Practical meditation training consisted of ten minutes of training distributed equally over three routines, namely focused attention to breath exercises (Anapanasati), focused attention to body parts (body scan) and Vipassana (focused attention to and observation of mental content appearing and disappearing) (Tomasino & Fabbro, 2016).

By undergoing fMRI testing before and after meditation training, the participants served as their own control. The fMRI measurement was divided into six blocks (of 230 seconds each), with a 90-second resting period in between each block. The participants were told to focus on their breath for the first three blocks and whenever their attention fluctuated, to attempt to refocus it on the breath. For the remaining three blocks, participants were instructed to focus on different bodily sensations and refocus if attention was lost. Afterwards the subjects filled out a questionnaire to determine their levels of attention, boredom, tiredness, joy, and well-being (Tomasino & Fabbro, 2016).

Tomasino and Fabbro (2016) found elevated activation in the right middle frontal gyrus, the right dorsolateral prefrontal cortex, the left caudate, and the left anterior insula (Tomasino & Fabbro, 2016). Another FA study also found activation in the right dorsolateral prefrontal cortex and ventrolateral prefrontal cortex when participants shifted their attention back to their breath after having lost their focus, and while they kept focusing their attention on their breath (Hasenkamp et al., 2012). The third area to demonstrate enhanced activity after meditation training was the left caudate, which is associated with emotional regulation (Tomasino & Fabbro, 2016). Following a later study conducted by Farb, Segal and Anderson (2013) that found that left caudate increases in grey matter volume as a result of meditation training, it was believed by the authors that the caudate is important for habitual direction of behavior and attention. The anterior insula is also known for producing feelings of well-being, and as mentioned previously, with arousal and valence (Tomasino & Fabbro, 2016). An activation of anterior insula along with dorsal anterior cingulate cortex was seen in FA meditators the moment they became aware that attentional focus was lost, suggesting that anterior insula and dorsal anterior cingulate cortex are involved in momentary conscious awareness (Hasenkamp et al., 2012). Thus, activations of left caudate and anterior insula are
in line with the explanation put forth by Lutz et al. (2008), which presents meditation techniques, as complex strategies with aims such as emotional regulation and well-being, as well as the ability to regulate attention. Taken together, these findings confirm the previous assumptions that the dorsolateral prefrontal cortex would be activated, as it is an area involved in conflict monitoring and is presumed to help with monitoring, sustaining, and orienting attention towards specific goals (Hasenkamp et al., 2012; Lutz et al., 2008).

**Deactivations.** In earlier described fMRI study on eight FA expert Theravada Buddhist monks, Manna et al. (2010) also discovered that there were several regions that indicated extensive deactivations in both hemispheres when comparing FA to the resting state. Deactivations were more predominant in the left hemisphere (six clusters) as opposed to the right (two clusters). In the left hemisphere, deactivations were observed in the anterior and posterior insula, the transverse temporal gyrus, the precuneus, the lateral anterior prefrontal cortex, the dorsolateral prefrontal cortex and the middle frontal gyrus. Meanwhile, two regions in the right hemisphere displayed deactivation: the superior temporal gyrus and the inferior frontal gyrus.

Manna et al. (2010) suggest that attentional focus in FA meditation is not only achieved by activations in the right medio-frontal areas but also by deactivation in the left prefrontal-lateral regions (the anterior prefrontal cortex, the dorsolateral prefrontal cortex and the middle frontal gyrus). Furthermore, the left precuneus may be responsible for self-invoked transition between meditational and non-meditational attention. Deactivation in right inferior frontal gyrus and the left posterior insula correlated positively with FA meditation expertise. This suggests that FA experts are better at sustaining temporary awareness on experiential content, and maintaining cognitive attentional focus.

In the fMRI study conducted by Lee et al. (2012), expert FA meditators demonstrated a greater deactivation in the right thalamus during baseline than novices. The authors speculate that this deactivation aids in attention by reducing the amount of mental effort necessary to complete attention tasks. A lengthy FA meditation practice might bring about a stable and clear mind, leading to better attentional stability (Lee et al., 2012).

In their eight-week meditation study, Tomasino and Fabbro (2016) found reduced activation in the anterior prefrontal cortex when they analyzed pre-and post-body scans in breathing meditation in contrast to respective resting states. The anterior prefrontal cortex is partially involved in the default mode network (DMN), a network of brain regions including the hippocampus, the posterior inferior parietal lobule, the temporoparietal junction, the precuneus, the posterior cingulate cortex, and medial prefrontal cortex, which is responsible
for mentalizing and mind wandering (Scheibner et al., 2017). Mentalizing can be understood as the capacity to understand that other people have beliefs, thoughts, and desires of their own (Gazzaniga et al., 2013). Mind wandering can be understood as non-task specific self-referential thinking, which is often related to a judgment of the current moment, contemplation of past experiences, and planning for future events (Scheibner et al., 2017). An extensive study undertaken on 5,000 people from 83 countries demonstrates that the human mind wanders almost 47% of the time, and when that happens people tend to feel less happy (Killingsworth & Gilbert, 2010). In their review article, Sood and Jones (2013) explain in that atypical activity in default mode network leads to negative emotional consequences as well as predisposing people to a variety of psychological disorders, such as posttraumatic stress disorder, depression, anxiety, and schizophrenia (Sood & Jones, 2013).

The fMRI findings of Tomasino and Fabbro (2016) showing deactivations in the anterior prefrontal cortex along with deactivation in the precuneus further support the results of various studies on how FA meditation deactivates regions linked to the default mode network. An fMRI study conducted by Brewer et al. (2011) found similar results when comparing the effects of FA meditation on expert and novice practitioners. The results indicated that FA meditators showed deactivation in the posterior cingulate cortex and the medial prefrontal cortex, two regions closely linked to the default mode network. However, as mentioned previously, an activation of medial anterior prefrontal cortex was seen in an FA study conducted by Manna et al. (2010), and an activation of the right precuneus was seen in the study by Lee et al. (2012), in contrast to the findings of Tomasino and Fabbro (2016) and Brewer et al. (2011).

Open Monitoring Meditation

On the basis that OM does not emphasize any particular explicit attentional focus but rather a momentary observation of ongoing experience, Lutz et al. (2008) proposed that OM cannot rely on brain sections involved in maintaining or engaging attention. They instead predicted that brain areas involved in awareness, monitoring and disengaging attention are affected. Lutz et al. (2008) also proposed that, due to the natural tendency to not cling to any phenomena, cognitive or emotional, it can be presumed that OM engages processes dealing with interoception, or perception of the internal states of the body. Regions thought to be involved include the somatosensory cortex, the anterior insula and the anterior cingulate cortex. Further predictions involve the regulation of limbic responses via the prefrontal regions.
Functional Neuroanatomy of OM Meditation

Activations. Based on theoretical models and experimental findings that tie each hemisphere to its own sets of specialized capacities, with the left hemisphere being linked with language and speech, conscious activities, and experiences (Gazzaniga, 1995), Manna et al. (2010) predicted that fMRI scanning would reveal an increased activation in the left fronto-parietal brain regions during OM meditation compared to other states. The fMRI study performed by Manna et al. on eight expert Theravada Buddhist monks was done in a two-by-two design. The findings in OM versus resting state contrast demonstrated activations in three left hemispheric regions: the superior temporal gyrus, the medial anterior prefrontal cortex and a cluster in superior parietal lobule that stretched towards the precuneus. These areas are commonly associated with normal resting state processes of self-reference, for which the default mode network can be responsible (Scheibner et al., 2017). The explanation for activation in these areas suggests that OM monks might engage the metacognitive observation of such self-referential phenomenal experiences evoked by the default mode network. This would be in line with Buddhist meditation and practice, in which the aims are to go beyond the mental states and perception of oneself as a separate subject (Manna et al., 2010).

The analysis of OM versus FA reveals more activation in left the dorsolateral prefrontal cortex, the lateral anterior prefrontal cortex, the medial frontal gyrus, superior parietal lobule/precuneus, and the anterior insula, together with right hemisphere lateral anterior prefrontal cortex, inferior frontal gyrus, the transverse temporal gyrus and superior frontal gyrus. However, it should be noted that the majority of these apparently greater activations occurred due to deactivations in those regions during FA meditation, rather than activations during OM meditation (Manna et al., 2010). Together, these findings seem to confirm the hypothesis that left fronto-parietal brain regions are activated by OM meditation. The fronto-parietal areas could help monks gain control over networks responsible for conscious access to sensory-related content, such as emotions and thoughts. Manna et al. (2010) demonstrated that OM experts activate the precuneus/superior parietal lobule in the left hemisphere, the parahippocampal gyrus, and the dorsal anterior cingulate cortex in the right hemisphere more than novices. The left precuneus showed similar patterns of activation in monks, across all contrasts indicating that the area might plausibly be responsible for the self-induced shift between meditative and resting states (Manna et al. (2010).

A recent study by Zeidan et al. (2015) presents new evidence indicating that OM meditation makes use of distinct brain structures by which pain-reducing effects are implemented, in contrast to fake mindfulness meditation and placebo cream with no analgesic
properties. These results demonstrate that pain-relieving effects are correlated with activation of higher-order brain areas such as the cingulate and the orbitofrontal cortices; these findings may further support the use of meditation in pain therapy situations. It was anticipated that the analgesic effects of OM meditation would be linked to greater activation in regions responsible for processing sensory information such as the insula and the secondary somatosensory cortex, as well as the anterior cingulate cortex and the orbitofrontal cortex, regions involved in higher-order functions. To test this, Zeidan et al. (2015) conducted a study using magnetic resonance imaging to measure cerebral blood flow.

A total of 75 men and women with an average age of 27 years participated in the study. Participants had no pain-related issues and all were right-handed with no prior experience of meditation. The study employed a randomized block-design procedure that matched participants based on sex and randomly assigned them to one of four groups. The four treatment groups consisted of OM meditation, placebo analgesic cream, fake OM meditation, and a control group. In the OM meditation group, participants were trained in OM meditation for 20 minutes each day for four days in total. Instructions resembled traditional OM meditation style: Participants were told to focus to the sensation of breathing without judging or evaluating arising thoughts or feelings. Unlike regular mindfulness practice, which encourages mindfulness in everyday situations, all practice outside of the instructed training routine was prohibited. The participants of the placebo group were told that they were participating in testing a new local analgesic gel that reduced the effects of pain over time. The fake OM meditation participants were instructed and trained in the same manner (posture, instruction time, closed eyes, training room etc.) as the OM meditation group, with the exception of the mindfulness component. Instead, fake meditators were told every few minutes that they were sitting in meditation and asked to take a deep breath. The control group was instructed to listen to an audiobook for the same amount of time as the other groups.

All groups were scanned pre-and post-intervention, while exposed to thermal manipulation of the skin of the right calf, in such a manner as to not induce tissue damage. The thermal manipulation was composed of two stimulation conditions: a neutral 35 degrees Celsius, and a painful 49 degrees Celsius. The intensity and unpleasantness of the perceived pain were assessed using a visual analogous scale that ranged from zero (e.g. no pain sensation or no unpleasantness at all) to ten (the most intense or unpleasant sensations of pain imaginable). The Freiburg Mindfulness Inventory scale was used to evaluate the level of
mindfulness. This scale reveals that OM meditation trainees scored 16% higher than the other groups after four days of training.

The results obtained by Zeidan et al. (2015) also reveal that all interventions decreased pain intensity and unpleasantness compared to resting state and the control group. Open monitoring meditation significantly decreased pain intensity by 27% and reduced the perceived level of unpleasantness by 44%. Fake OM meditation led to a reduction of pain intensity by 8% and of perceived level of unpleasantness by 27%. The placebo decreased pain intensity by 11% and unpleasantness by 13% (Zeidan et al., 2015).

Aside from the extended pain reduction in OM meditation condition compared to the other groups, there were also differences in neural activations. Activation in right anterior insula and bilateral subgenual anterior cingulate cortex, and the orbitofrontal cortex were associated with a decreased rating of pain intensity. Bilateral activations in the frontal operculum and the left inferior frontal gyrus were associated with a decreased rating of pain unpleasantness. The right anterior insula was likely responsible for tuning the sensory input, and the subgenual anterior cingulate cortex could be involved in shifting attention between breath and pain. The orbitofrontal cortex is the region believed to engage distinct reassessing processes that evaluate pain sensation. As hypothesized, OM meditation generated more activation in brain areas linked to top-down cognitive alteration of pain than the placebo (Zeidan et al., 2015). These results reaffirm the practices and aims of OM meditation, as an accepting and non-judgmental approach would make a participant more tolerant of pain.

**Deactivations.** In their study, Manna et al. (2010) found no deactivation between experts in OM meditation and their resting state, indicating that the subjects’ normal resting states were similar to their OM states. When a comparison was made directly between OM and FA type of meditation, a deactivation of the right medial anterior prefrontal cortex and right dorsal anterior cingulate cortex was observed.

In the MRI study conducted by Zeidan et al. (2015), some deactivations were observed in relation to painful stimuli after conducting an OM meditation intervention. These deactivations were observed bilaterally in the thalamus and the periaqueductal gray matter regions which assist the processing of nociceptive and low-level sensory information. The thalamus in particular is a vital region responsible for transmitting incoming sensory information and it operates as a selectively filtering gate of sensory input (Fox et al., 2016). Compared to the placebo, OM deactivated more parts of the default mode network. Although Zeidan et al. (2015) provide no explanation with regard to pain reduction, they note that OM is a cognitively active practice; this is in contrast to a placebo, which is a more passive state.
Interestingly, all of the remaining groups showed an increase in the left dorsolateral prefrontal cortex and thalamus. Fake mindfulness produced a deactivation of the anterior cingulate cortex in direct contrast to the OM routine, suggesting that pain relief is modulated by different mechanisms. Pain relief was positively linked to lower rates of respiration in the other groups, whereas the analgesic effect of OM meditation was independent from rates of respiration. This suggests that OM meditation leads to pain relief via regulation of top-down systems as demonstrated by the activation of large parts of the prefrontal cortex.

**Electroencephalographic Studies**

Apart from the fMRI studies described previously, there are also studies that have employed other methods, such as electroencephalography (EEG) investigation, to further illuminate the similarities and differences between FA and OM meditation practices. EEG is a non-invasive method in neuroscience that measures the electrical signal produced by populations of neurons in the cortex. The measurement is done by placing an elastic cap, containing usually between 20 and 256 electrodes on the subject (Gazzaniga et al., 2013). The results from these electrical signals are divided into five segments depending on the frequency they produce, ranging from delta (<4 Hz), to theta (4-8 Hz), to alpha (8-12), to beta (13-30 Hz), and to gamma (30-50 Hz) (Stern & Engel, 2013).

**Focused Attention Meditation**

In a study conducted by Travis and Shear (2010), it was proposed that meditation could be assigned into specific categories based on EEG frequencies, as each meditation category underlies different cognitive processes. As mentioned previously, FA is characterized by a narrower span of attention, as the practitioner attempts to direct and maintain focus on a single object of choice without being distracted. According to Travis and Shear (2010), various FA practices are associated with particular EEG frequencies, including the beta 2 (20-30 Hz) and gamma (30-50 Hz) bands. These frequency bands seem to be especially active in practices where deep focused attention is directed on chosen objects in the field of experience.

One such study conducted done by Huang and Lo (2009) attempted to discover how deep FA meditation affects the brain. The authors speculated that beta power is affected by meditation but did not measure gamma power. In this study, Huang and Lo employed EEG method to investigate differences in brain activity between 23 experienced meditation practitioners (with an age average of 31.5 years) from the Zen tradition and 23 matched control subjects with no prior meditation experience. Meditation practitioners had an average practice experience of 8.4 years (ranging from two to twelve) in a concentrative form of
practice known as Zen Chakra, where focus is directed towards a specific body part. Meditators were instructed to sit in a meditation-specific position (called the lotus position) with eyes closed during the meditation, while control participants were instructed to sit still and relax their bodies and minds without falling asleep. The scanning session lasted forty minutes and was divided into three segments: first twenty minutes, then another ten minutes, and finally another ten-minute segment. Their results reveal that meditators present an overall larger EEG activation, mainly in the anterior, temporal and occipital areas. As speculated, FA meditators as demonstrated a greater activation of beta power in the occipital lobe, along with alpha 1 power in the frontal lobe when compared to the resting state. An overall decrease in theta power was also observed.

Their results further indicate that, compared to the control group, meditators had an overall EEG increase in the anterior, temporal and occipital regions. They also experienced an increase in alpha 1 band power in the frontal region and beta power in the occipital region at the beginning of meditation. In contrast, beta 2 (20-30 Hz) activity was higher in the mid and last segment of meditation session. Meditators had less theta power activation than the controls (Huang & Lo, 2009). Although Travis and Shear (2010) do not explicitly indicate that the alpha bands are connected to FA meditation, they explain that alpha 1 seems to be involved in anticipation, states of watchfulness, and attention to oneself, while beta 2 is involved with deep focused attention (Travis & Shear, 2010). Meditator subjects themselves stated that in the beginning and middle part of meditation, their focus was more diffuse and widespread, which would explain the more peacefully relaxed and watchful alpha 1 state. As their concentration improved on the point of focus, more beta 2 activity was observed, indicating deeper concentration and fuller attentive awareness (Huang & Lo, 2009).

Huang and Lo do not elaborate on theta power differences, but Travis and Shear (2010) suggest that theta power, which emerges from the anterior cingulate cortex and the medial prefrontal cortex and seems to involve tasks related to working memory, observation of inner processes, and mental imagery, is expected in OM, in which the observation of momentary experience without judgment or control is a key element. This could explain why FA meditators present decreased theta power while controls reveal an increase: The meditators actively focused on their chakra, while the controls did not focus on anything in particular but were merely relaxed with eyes closed (Huang & Lo, 2009). Such relaxation might arguably involve the observation of internal processes and mental imagery to some extent, which supports the argument made by Travis and Shear (2010), although this is entirely speculative by the author of this report.
A later EEG study by Saggar et al. (2012) demonstrates repeated reduction in beta power bilaterally in the central anterior and posterior regions of the brain. Individual alpha frequency (IAF) decreased in correlation to the amount of FA practice in both groups. Predictions were made regarding the effects of FA meditation on cortical areas. Saggar et al. hypothesized that, due to the nature of breath-related focus in the oral and nasal face area, FA meditation leads to activations in regions involving tactile sensory processes. They also predicted decreased activity in alpha and beta power across central and parietal regions, due to their involvement in somatosensory processes and attention. Furthermore, they anticipated changes in IAF due to FA training, based on indications from previous studies, that found an overall alpha frequency reduction. Finally, Saggar et al. suggested a correlation between FA training experience and increased cortical activity (less alpha and beta power) was made. Data from 44 participants, divided into a retreat group (n=22), and a waiting list control group (n=22) was used to interpret the results. All participants were matched on sex, age, and meditation experience. The retreat (FA training) group lived and practiced the Samatha (deep focus on breathing) style of meditation at a meditation center for approximately six hours daily, over a period of three months. Once the retreat was over for the initial group, the waiting list controls received FA meditation training in the same manner (Saggar et al., 2012). The EEG data was acquired during six minutes of focused breathing meditation spread over three periods: the beginning, middle, and end of the retreat. There was no significant difference between the groups in term of meditation experience (retreat: \(M=2855\) h, control: \(M=2272\) h) or other variables (Saggar et al., 2012).

Results reveal that the initial retreat group had a reduction of beta band power bilaterally in the central anterior and posterior regions of the brain, along with a reduction in IAF as correlated to the amount of FA practice. Repeated reduction in beta and IAF were seen in the control group when they received identical FA training. Less alpha and beta power has been linked to cortical excitability, the ability to discriminate between stimuli and suppress distractions (Saggar et al., 2012). Although decreased beta power findings are not in line with the findings of Huang and Lo (2009), Saggar et al. explain their results by referring to previous studies where alpha and beta power activated cortical structures in an inverse way (i.e., lower beta power leads to more activity). This explains reduction of alpha and beta power during tasks related to focusing attention on tactile stimuli: During the six-minute closed-eyes meditation scanning, practitioners were instructed to pay particular attention to the subtle sensation of breathing in their nostrils and to maintain their focus.
Based on previous findings indicating that IAF is involved in cognitive load and cognitive resource management, it is reasonable to assume that FA meditation could affect the resources needed for reorienting and maintaining focus on the sensation of breathing (Saggar et al., 2012). However, since changes in alpha activity have been observed in numerous contemplative practices, its full functional potential and significance in FA remains unclear (Cahn & Polich, 2006). All of the initial predictions of Saggar et al. were confirmed with the exception of the last one. Beta band power was unaffected by the FA experience. However, a decrease in alpha band power was also correlated with time spent in FA meditation, indicating that extended FA meditation experience leads to additional IAF reduction. The study had limitations which could have contributed to confounders due to unrelated factors. The silent solitude and natural wilderness could offer cognitive advantages unrelated to meditation training. Furthermore, the retreat was located 2,500 meters above sea level, which could affect EEG recordings. Finally, the commitment to the worldview of Buddhism, as well as the teachers’ guidance, may also have affected levels of motivation (Saggar et al., 2012).

**Open Monitoring Meditation**

Detached, non-judgmental awareness of ongoing experience in the present moment, mainly as a way of familiarizing oneself with the cognitive and emotional patterns characterized by OM meditation (Lutz et al., 2008; Travis & Shear, 2010) would according to Travis and Shear be accompanied by mid-frontal theta power, based on its association with studies demanding working memory, mental imagery and self-control. This frequency activation is related to structures such as the anterior cingulate cortex and the medial prefrontal cortex (Cahn & Polich, 2006; Travis & Shear, 2010).

In a study conducted Cahn et al. (2010), there are several frequency associations in OM meditation. The frontal delta was seen to decrease during meditation, particularly in meditators who did not report drowsiness during meditation. There was also a relative increase in frontal theta band power, and a large increase in occipital gamma which was strongest in meditators with at least ten years of experience. The single group-design study performed by Cahn et al. involved sixteen participants from a local Vipassana meditation center. All individuals had meditated daily for the previous year and had been practicing meditation for an average of twenty years. The EEG recording was performed during sitting meditation with eyes closed, and in a control state where participants were told to allow their minds to wander freely on emotionally neutral thoughts as a means of simulating an everyday "mind-wandering" state. Participants wore headphones and a series of tones announced the
end of the 21-minutes meditation and control-state sessions. Directly afterward, the participants filled out a form that estimated their level of sleepiness or drowsiness during the session.

The nature of Vipassana meditation emphasizes the need for reduced automatic reactivity and enhancement of awareness, to both external and internal stimuli. On the basis of this Cahn et al. theorized that meditation would enhance activation in frontal lobe theta, alpha and in gamma band power, compared to the control state. The results confirmed this initial assumptions: Vipassana meditation led to a decrease in frontal lobe delta power, an increase in frontal theta power, and an extensive increase in gamma power in the parieto-occipital region. Although delta power is closely related to sleep and, if observed in the state of wakefulness, it seems to be linked to pathology (Travis & Shear, 2010), the results of this study attribute the decrease in delta power to a higher state of awareness on the part of meditators, as those who reported lower levels of drowsiness also displayed lower levels of delta power. The increase in theta power (Cahn et al., 2010), which is supposedly originating in the anterior cingulate cortex and medial prefrontal cortex and is related to attention, mental imagery, and observation of internal processes, seems to correspond well to the definition of OM meditation, as the observation of internal processes without judgment, and enhanced attention are part of the practice (Cahn & Polich, 2006; Travis & Shear, 2010). Gamma power is associated with selective and perceptual awareness and is thought to be involved in feature binding (i.e. binding stimulus features into a coherent whole). A significant correlation between gamma power and the daily practice of meditation was observed, indicating that continuous practice leads to lasting changes. Thus, the overall results seem to indicate that an OM style of meditation leads to a higher awareness of external and internal stimuli, enhanced attention, and a reduction in automatic reactivity. Limitations regarding the design of this study mean that the observed effects cannot be clearly attributed solely to meditation, as no control group was present. Due to the practitioners’ extensive experience in meditation, they reported difficulties staying in a neutral state while seated in the meditation position. They simply had trouble avoiding falling into a meditative state (Cahn et al., 2010).

**Discussion**

The main purpose of this thesis was to compare and contrast two of the main categories of meditation. FA and OM differ in terms of aim and were thus expected to affect the brain in somewhat different ways. In FA meditation, a clear, calm, and peaceful state in which reduction with emotions and thoughts are slowly reduced is achieved by narrowing the focus
of attention (Brefczynski-Lewis et al., 2007; Lee et al., 2012). Systems related to selective attention, sustained attention, and conflict monitoring are thought to be involved (Lutz et al., 2008). OM meditation, in contrast, involves a more open perceptive state of awareness on the content of momentary experience, with no particular point of focus. OM was thus proposed to involve areas responsible for interoception, awareness, and monitoring and to disengage attention from distractors, along with regulating the limbic system via the prefrontal cortex (Lutz et al., 2008). On the basis of the initial predictions of Lutz et al. (2008), this thesis considered several studies to determine how FA and OM are both similar and distinct from each other. In this section, I first discuss the activations and deactivations caused by FA meditation. Thereafter, I address the activations and deactivations due to OM meditation.

Lee et al. (2012) demonstrated that FA meditation can aid in attention, as their study reveals that FA experts made fewer commission (0.7% vs 2.0%) and omission errors (2.4% vs 13.8%) than novice meditators (Lee et al., 2012). Neural findings seem to provide an explanation for such results. Neural activations following FA meditation were observed in the middle frontal gyrus (Manna et al., 2010; Tomasino & Fabbro, 2016), the inferior frontal gyrus (Lee et al., 2012) and the dorsolateral prefrontal cortex (Hasenkamp et al., 2012) were all activated in the right hemisphere and the superior frontal gyrus in the left hemisphere (Lee et al., 2012), along with bilateral dorsolateral anterior cingulate cortex activation (Manna et al., 2010), in both within and between group condition. In Hasenkamp et al. (2012), the region of dorsal anterior cingulate cortex seems to indicate its importance in conflict monitoring.

The activations in the dorsolateral prefrontal cortex and the dorsal anterior cingulate cortex confirm the initial proposition of Lutz et al. (2008), who suggested that FA could affect regions involved in maintaining attention and conflict monitoring. The activation of the right ventrolateral prefrontal cortex, as seen in Hasenkamp et al. (2012), further confirms findings regarding selective attention. Activations were seen in the left anterior insula and, in the left caudate in experts viewing happy faces during emotional processing tasks (Lee et al., 2012; Tomasino & Fabbro, 2016). This suggests that these regions assist in reaching attentional stability by suppressing emotional stimuli and that they aid in emotional regulation, conscious awareness, and well-being. Electroencephalographic findings suggest that FA meditation produces frequencies in alpha 1, which seems to involve anticipation, watchfulness and paying attention to oneself, while more beta 2 frequencies mean deeper concentration and awareness. This confirms that FA produces electroencephalographic activation frequencies dealing with attention (Huang & Lo, 2009).
In summary, FA seems to primarily activate the right medial/lateral prefrontal cortex regions, along with the bilateral dorsal anterior cingulate cortex, the left caudate and the anterior insula. All of these areas deal with maintaining attention on objects of focus, monitoring conflicts, and selective attention, and regulating emotions as a means of aiding attention. Together with electroencephalography activations in alpha 1 and beta 2, these findings seem to align with the notion that FA meditation affects regions involved in sustained attention, selective attention and conflict monitoring. This is in line with the theory of FA meditation, as it involves focusing attention on a single point, and if a goal conflicting thought or emotion emerges, encourages redirecting attentional to the central focus. In this way, all attentional regions are involved in FA meditation (Lutz et al., 2008). Focused attention meditation seems to assist attention by suppressing emotions, encouraging conscious awareness of body states and achieving well-being, by engaging parts of the insular cortex.

Deactivations following FA meditation were found predominantly in the left prefrontal cortex region, along with anterior/posterior insula, and precuneus (Manna et al., 2010). This indicates that attentional focus in FA might be a result of widespread deactivations in the left prefrontal cortex region. Less activation in right thalamus helps attention by reducing mental effort in attentional tasks, leading to a clear and stable mind by which attentional stability is achieved (Lee et al., 2012). Deactivations in parts of the default mode network as seen in (Tomasino & Fabbro, 2016), and in (Brewer et al., 2011) suggest that FA meditation could prove to be a useful tool in terms of reducing mind-wandering. I find this fascinating, especially since OM seem to activate parts of the default mode network as seen in (Manna et al., 2010). This contrast demonstrates that FA may be better at targeting regions that are responsible for mind-wandering. However, as seen in Zeidan et al. (2015), parts of the default mode network were also deactivated, which means that OM also has the potential of affecting regions of the brain that deal in mind-wandering. My speculation is that if research is done where FA and OM are directly compared on their effectiveness in affecting the default mode network, FA would provide better results based on its aim-related practice. I find the topic of meditation in relation to the default mode network interesting; therefore, I would like to see more research done on this particular issue.

In summary, FA meditation could lead to attentional focus as a result of large deactivations predominantly in the left prefrontal cortex region. Electroencephalography beta reduction can help excite cortical regions responsible for attention and somatic sensations tied to FA practice, and alpha frequency might further help attentional aspects by decreasing cognitive load and resource management. Reduction in the insular region might help attention
by reducing distracting elements, and less thalamic activity can provide a clear and stable mind by which attentional stability can be achieved. Furthermore, deactivations of regions in the default mode network can help FA meditators reduce mind-wandering and mentalization, leading to attentional stability and well-being.

Overall these deactivations seem to support the initial predictions made by Lutz et al. who suggested that FA is more involved in regions dealing with attention aspects. Although no predictions were made by Lutz et al. (2008) with regard to regulation of neural emotional areas, nevertheless such changes seem to correspond to the context of FA meditation, in which unwanted mental (or emotional) content is disregarded for the sake of the attentional focus (Lutz et al., 2008).

Open monitoring meditation activates left parts of the DMN, which are responsible for self-referential processes and, which would be nonjudgmentally observed in accordance with Buddhist aim of OM meditation (Manna et al., 2010). Large left fronto-parietal and insular regions were activated due to OM meditation, suggesting more conscious access to thoughts and emotions. The fact that OM helps with access and awareness of emotions and thoughts could prove to be beneficial in terms of pain regulation as seen in Zeidan et al. (2015). However, the results demonstrating that OM activates DMN, in contrast to FA, raises an important question that has not been addressed in the literature so far. There is overall little talk about the negative aspects of meditation practice in the literature. What if participants training OM meditation activate DMN, gain better awareness of their negative mental or emotional aspects, without being able to meet such qualities with an accepting and open mind? The instructions of OM state that all mental and emotional content is to be observed, but the literature mentions nothing about how such sensitive awareness to the occurring experience could possibly lead to enhanced anxiety, stress or panic-attacks. Meditation overall seem to be praised and has received alot of attention lately in terms of its benefits, but a lack of research addressing potential harmful effects of meditation seem to be missing. I would like to see more such research.

In relation to pain reduction, OM produced an analgesic effect by reducing pain intensity and pain unpleasantness to a greater degree than the placebo and the fake mindfulness routine (Zeidan et al., 2015). It is difficult to relate this finding to FA meditation, as there seem to be little research done on how FA affects pain perception. One study done on FA in relation to pain perception demonstrated that novice FA practitioners experienced higher levels of pain intensity and pain unpleasantness comparing to expert FA practitioners.
(Grant & Rainville, 2009). This underpins that not every type of meditation technique is beneficial for everything.

Deactivations following OM meditation were found in bilateral thalamus and PAG, and in parts of the DMN. Indicating that OM meditation is an active cognitive state and that such practice deactivates regions which assist in processing painful sensory information. OM meditation leads to enhanced pain reduction, as compared to other states in (Zeidan et al., 2015). EEG studies show that OM meditation decreases frontal delta, especially in practitioners reporting lower levels of drowsiness, leading to higher awareness. OM deactivations are in line with Lutz et al. (2008) where an open state of awareness is described.

**Conclusion**

Overall, the results of the various studies analyzed in this paper seem to agree with the predictions put forth by Lutz et al. (2008), concerning FA and OM being in separate categories, with distinct neural mechanisms underlying the different cognitive and emotional aspects of each practice. The primary conclusion is that FA and OM engage different hemispheres. FA meditation mostly impacts right medial/frontal prefrontal cortex, parts of the limbic system, and the anterior cingulate cortex as a way to select and sustain attention on task-specific goals and monitor goal-conflicting activities, by refocusing from arising distractors. Focused attention meditation deactivates the parts of the default mode network responsible for non-task specific activities such as mind-wandering, possibly leading to better attentional quality and enhanced well-being. Focused attention meditation also produces changes in EEG frequencies such as beta, beta2, and theta. In contrast to FA, OM meditation is predominantly associated with activations in the left fronto-parietal and insular region, which help OM meditators gain access to regions dealing with conscious access to thoughts and emotions, which in turn affects pain perception. The insula is also an important region involved in emotions. It is involved in both FA and OM. In FA it might help with attentional aspects by suppressing emotional elements. In OM it helps with introspection. OM compared to resting state activates the default mode network, which resembles brains normal state. In task-specific conditions parts of DMN are instead deactivated. The explanation for this is understood in terms of Buddhist tradition and aim, where OM with its present and nonjudgmental attitude would allow processes made by DMN to happen. Compare this to FA, where self-referential processes provided by DMN would be suppressed in a goal-specific manner. OM meditation reduces pain perception by affecting regions linked to cognitive
modulation of pain. Regarding EEG changes, OM affects theta and gamma waves. Thalamic involvement was observed in both FA and OM meditation. Its function as a sensory signal relaying structure is in agreement with both practices. In FA it might help attain a clear and stable mind, thus helping attention and in OM it might help reduce painful sensory information.

The primary conclusion of this thesis is that there is a relation between FA and OM, in terms of hemispheric lateralization. Focused attention meditation engages mostly right prefrontal cortex as compared to OM which engages mainly left fronto-parietal regions. Both practices engage the insula and, the thalamus in aim specific manner. Insular engagement in FA leads to better attention, and in OM it engages introspection. The thalamus in both practices helps with relaying sensory information.

Secondary conclusion is, that we don’t understand what role hemispheric lateralization plays but it is clearly affected by the different practices. Future research would therefore benefit from rigid methodological studies where hemispheric lateralization of FA is directly compared to OM. Last conclusion is that there is a relation between FA and OM in terms of activation of the default mode network. Focused attention seems to deactivate the default mode network, in contrast to OM, which activates parts of the default mode network.

**Future research**

Future research could benefit from reevaluation of the proposed categorizations. A great deal of research in this area builds upon the initial propositions made by Lutz et al. (2008). In the light of the electroencephalographic categorization made by Travis and Shear (2010) and the categorizations in Fox et al. (2016), it could be beneficial for future research to reevaluate the proposed categorizations. The closer the scientific community can come to a consensus regarding how meditation should be defined, its categorizations, and how it should be measured, the better it will be for practitioners and researchers.

**Limitations**

A limitation of this thesis with regard to meditation research becomes evident in terms of methodology. A single category of meditation could be studied in different contexts, places, and with various tasks related to it. Variables such as diet, amount of sleep and resting state in between testing conditions are some of the aspects which are normally not controlled for and, may therefore affect the results when measuring meditation. Furthermore, since many meditative traditions originate from Eastern traditions, it could be beneficial to understand cultural as well as personal factors. Future research should focus on better methodology and
understanding of the traditions from which these meditation practices derive. Another limitation of this paper is that it focused solely on the neural correlates of FA and OM. If other aspects of meditation research had been sufficiently investigated, such as further behavioral aspects, immunology, or clinical applications, perhaps some other questions could have been answered, such as how meditation affects the behavior of those who practice meditation, how meditation affects the human immune system and, how different meditation practices can be used to treat clinical conditions.
References


