The Effect of Mindfulness Meditation on Affect and Attention
An Empirical Study

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Abstract

In daily life there are numerous experiences and events that divert people's attention and cause stress, which may be linked with aspects of ill-being and lowered well-being. Mindfulness meditation may alleviate such issues. Mindfulness can be summarized as a form of awareness and attention in the present that is characterized by an open-minded and non-judgemental perspective, and meditation as a group of practices that engage many of the same processes and may involve mindfulness. There is evidence that both mindfulness and mindfulness meditation are associated with activity in brain regions relating to, for example, attention, emotion-regulation, and bodily awareness. Consequently, mindfulness meditation was hypothesized in the present study to improve attention as measured by the Attention Network Test, and decrease negative affect as measured by the Positive and Negative Affect Schedule when compared to a control condition. The mindfulness meditation instructions employed were largely based on the work of Kabat-Zinn (1982). 14 participants were recruited to the study, and 7 of them completed the experiment. 3 participants were randomized to the experimental group, and 4 to the control group. Results were largely contrary to the hypotheses, with only executive attention having statistical significance (p < .05) and supporting one hypothesis. Although effect sizes were on average large for the variables of the study, the small sample size may have limited the power and increased the risk for type-II errors.

Keywords: attention, emotion, meditation, mindfulness, neural correlates
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The Effect of Mindfulness Meditation on Affect and Attention: An Empirical Study

Each life has stressful and mindless moments that disperse attention in every which way. Research has indicated that mind-wandering is commonly associated with lowered well-being (Franklin et al., 2013; Killingsworth & Gilbert, 2010) and that psychological distress is strongly connected to chronic pain and mental disorders (Blyth et al., 2001; Magni, Caldieron, Rigatti-Luchini, & Merskey, 1990). Stress may be caused by mundane events but produce similar effects as in combat situations (Lazarus, 1993), is linked with workplace sick leave (Lomas, Medina, Ivtzan, Rupprecht, & Eiroa-Orosa, 2017), and can cause neurotoxic damage due to cortisol release (Khalsa, 2015). Additionally, mindlessness can reflect deficiencies in attention and a defensive stance where percepts are ignored (Brown & Ryan, 2003).

Meditation is a process that generally involves a mental development or refinement and may facilitate concentration, joy, or a calm state of mind (Walsh & Shapiro, 2006). Both mindfulness and meditation can be said to concern present-moment attention and awareness (e.g., Baer, 2003), and improve health in several ways (e.g., Eberth & Sedlmeier, 2012; Greeson, 2009). As such, mindfulness meditation (e.g., Kabat-Zinn, 1982) may be one method to ameliorate elements of ill-being and deficiencies in attention.

Further, Buddhist practice, which meditation is derived from, has as a central goal the elimination of suffering and the premise that this must concern altering one's emotional and cognitive states (Lutz, Dunne, & Davidson, 2007). Therefore, it appears germane to apply mindfulness meditation to the alleviation of facets of ill-being and improvement of attention.

A purpose of this paper is to provide an overview of the extant literature on the topics of mindfulness and meditation and present prominent and relevant research to clarify these phenomena, including their associated neural correlates. This literature outline is provided to serve as bedrock for the main purpose of this paper: an empirical study that will be conducted to investigate the short-term effects of mindfulness meditation (For more details, see the Method section).
Article searches were conducted in the databases PubMed, MEDLINE, Scopus, Web of Science, and Google Scholar using key words such as mindfulness, meditation, neural correlates, and combinations thereof. References of select articles were additionally examined to follow up both older and newer research in the respective fields and to identify recurring authors.

The paper will begin with an overview of the concept of mindfulness, after which different views and theories on mindfulness will be presented. Afterward, meditation will be discussed in a limited context and related to mindfulness and methods such as open monitoring. Moreover, criticism on mindfulness and meditation research is considered. And meta-analyses on the impact of meditation and mindfulness on ill- and well-being facets will be briefly reviewed. The neuroscience of mindfulness will be examined and divided into sub-categories. Functional magnetic resonance imaging (fMRI) studies will be introduced, and their results displayed alongside some considerations for their design and limitations. A cursory overview will be provided for other tools measuring brain activity, and a few studies on indirect measurements of attention networks are presented. In addition, review articles and meta-analyses on mindfulness and meditation will be described to broaden the perspective and limit bias. Following this, the main findings will be summarized as a basis for the empirical study, and the purpose and hypotheses of the study presented. The study proper is then described, including participant and procedure-related information. Next, the measurement scales used in the study will be reviewed. Subsequently, the obtained data of the experiment will be analyzed, and this is succeeded by a discussion concerning the results. The discussion additionally contains a scrutiny of the limitations of the experiment, future directions, and a conclusion regarding the overall study.

**Mindfulness**

Ahir (as cited in Wheeler, Arnkoff, & Glass, 2017) states that Mindfulness arose over 2,000 years ago from Buddhist meditation techniques. Fundamental elements of mindfulness are usually described as receptive or conscious awareness and attention to experiences in the present (e.g., Brown & Ryan, 2003; Kabat-Zinn, 2003; Niemiec et al., 2010; Van Dam et al., 2018a). Further,
Mindfulness is characterized by a non-judgemental and open-minded attitude, among other attributes such as intentionality (Brown, Ryan, & Creswell, 2007b; Chiesa, Calati, & Serretti, 2011; Kabat-Zinn, 2003). Mindfulness may therefore select attention to extero- and interoceptive information (McConnel & Froeliger, 2015), and function to increase behavioral regulation and disengage individuals from automatic thoughts (Brown & Ryan, 2003; Niemiec et al., 2010). According to Hölzel et al. (2011), a pillar of mindfulness-awareness of the body-was taught as the first frame of reference within Theravada Buddhism.

Moreover, mindfulness can be said to contain a non-elaborative element (Chambers, Gullone, & Allen, 2009), and this view of mindfulness can be explicated as relating to the intentional use of sustained attention on occurring cognitive, emotional, and sensory experience (Epstein, 1995) that does not pertain to the judging of said experience (Kabat-Zinn, 2003).

Perspectives on the Nature of Mindfulness

As relayed by Cullen (2011), mindfulness may be viewed as referring to more than the meaning derived from its Buddhist origin of sati, which concerns a kind of attentiveness (For an overview of these definitional terms, see Vago & Silbersweig, 2012). Rather, mindfulness may as a central component relate to the ability to perceive events in the world in a manner not distorted by mental states (e.g., emotions and moods; Cullen, 2011).

Comparably, the concept of reperceiving relates to the ability to disidentify with contents of experience (e.g., emotions and thoughts) and shift perspectives of 'subject' to 'object' to achieve greater coherence and objectivity (Shapiro, Carlson, Astin, & Freedman, 2006). Such a process is said to be attainable through mindfulness, as reperceiving might be described as a mechanism intrinsic to mindfulness, and is thought to lead to other mechanisms. One such additional mechanism might be self-regulation (SR). By cultivating non-judgemental attention or awareness automatic habits, such as behaviors or thoughts, may decrease as the individual has a greater degree of freedom with which to understand and interrupt their own patterns (e.g., to avoid using alcohol to cope with anxiety and instead perceive anxiety as an impermanent emotional state; Shapiro et al.,
Baer, Smith, Hopkins, Krietemeyer, and Toney (2006) analysed mindfulness questionnaires to investigate the relationship between mindfulness and related constructs. Based on confirmatory factor analysis, the questionnaire facets nonreact, nonjudge, act with awareness, and describe appeared to constitute a larger mindfulness construct. Thus, it might be concluded that to desist from automatic reactions to experience (non-reactivity) and from judgement about one's experiences (non-judgement) are central parts of how to be mindful. However, questions concerning differences on what mindfulness is and what it might lead to (i.e., its outcomes) are important in not confounding the concept of mindfulness with its practice (Baer et al., 2006).

Chambers, Gullone, and Allen (2009) state that scientific definitions of mindfulness can be juxtaposed based on if they identify awareness (e.g., Brown & Ryan, 2003), acceptance (i.e., non-reactivity or non-judgement) and awareness (e.g., Bishop et al., 2004; Kabat-Zinn, 1982), or similar behavioural factors such as observing and acting with awareness (e.g., Baer et al., 2006) as the centrally defining features of mindfulness. Acceptance, in the context of mindfulness, may be delineated as a form of non-reactive awareness where a person's experience is examined in the absence of bias and habitual responding based on motivation to approach or avoid (Chambers, Gullone, & Allen, 2009).

Lutz et al. (2015) attempt to avoid many of the issues concerning the term itself (e.g., the differentiation between religious or spiritual perspectives and goals of mindfulness and psychological and neuroscientific counterparts), and instead advocate identifying mindfulness as a family of similar phenomenological states that emanate from the interaction of three main processes (i.e., meta-awareness, object orientation, and dereification) and four secondary characteristics (i.e., effort, clarity, stability, and aperture). Some researchers (e.g., Bernstein et al., 2015) use similar phenomenological mindfulness explanations as Lutz et al. (2015), but many other researchers (e.g., Brown & Ryan, 2003; Kabat-Zinn, 2003; Lindsay & Creswell, 2017) embrace the term in a manner more in line with its historical foundation (i.e., as related to sati, among other concepts).
Brown, Ryan, and Creswell (2007a) contrast mindfulness with self-focused attention and self-awareness, stating that mindfulness relates to an unbiased and open-minded “awareness of and attention to inner experience” (p. 273) that concerns occurring events rather than mental accounts of the self. However, other researchers (e.g., Baer et al, 2006; Masicampo & Baumeister, 2007) have proposed that there exist close connections between self-focused attention, self-control—a type of SR—and mindfulness. But Brown, Ryan, and Creswell (2007a) reject these ideas on the basis that (a) the evidence displays divergent results for self-focused attention and mindfulness, (b) there exist differences in operational definitions of self-control and mindfulness, and (c) mindfulness tends to facilitate SR instead of being a result of it.

Monitor and Acceptance Theory (MAT) proposes two chief components to explain mindfulness effects (Lindsay & Creswell, 2017). MAT states that attention monitoring (e.g., present-moment awareness) is sufficient for the improvement of cognitive outcomes (e.g., working memory, selective attention). But for improvement in stress, affective, and physical-health outcomes, training is required in both acceptance (e.g., a non-judgemental and open attitude) and attention monitoring according to MAT (Lindsay & Creswell, 2017).

Bishop et al. (2004) proposed an operational definition of mindfulness that relates to two separate components: the regulation of attention as a focus on present-moment experience, and an approach to all experience that is based in openness, curiosity, and acceptance. Bearing in mind these ideas of Bishop et al. (2004) and Lindsay and Creswell (2017), it thus appears that central concerns of mindfulness are the modification of one's attitude toward experiences (e.g., one's inclination to judge and value events) and attention to current experiences.

On a similar note, Lomas et al. (2017) describe the associated decentered perspective achieved while in mindful states of mind: a view which refers to the capacity to observe internal or external events in a detached and impersonal manner. Shapiro et al. (2006) argue that such a perspective is a meta-mechanism of action that is related to other aspects such as SR, and that SR and other aspects (e.g., behavioral, emotional, and cognitive flexibility) are influenced by the
decentered perspective to improve well-being and cause other positive outcomes.

In trying to clarify decentering and related phenomena, Bernstein et al. (2015) have proposed a model that transcends the associated constructs (e.g., cognitive distancing, reperceiving, self-as-context) and consists of three interrelated processes: (a) meta-awareness (i.e., awareness of one's own subjective experience or the contents of consciousness), (b) disidentification from internal experience (i.e., a detached experience of one's internal states), and (c) reduced reactivity to thought content (e.g., avoiding social situations less due to negative thoughts, or not elaborating as much on negative emotions). Lutz et al. (2015) have clarified that the term reactive (or non-reactive) in this context is associated with the mindfulness aspect of being non-judgemental. Reactive responses display affectively-valenced patterns and tend to relate to narrative or self-related schemas (Lutz et al., 2015).

Accordingly, Bernstein et al. (2015) group the various constructs under their decentering model based on the extent to which they engage the three processes of the model. For instance, although mindfulness is described as only relating to the meta-awareness process in itself it may generate disidentification as described by the decentering model (Bernstein et al., 2015). Meta-awareness has been described as a way for an individual to adjust their behavior, and may therefore be seen as a form of SR (Vago & Silbersweig, 2012).

Hölzel et al. (2011) argue that mindfulness may be described as functioning, by and large, through four components: (1) attention regulation, (2) body awareness, (3) emotion-regulation (ER), and (4) change in perspective on the self. While engaging in mindfulness practice (e.g., mindfulness meditation) attention may be regulated by the focusing of attention on an object such as the breath, and this practice can result in less distraction both during mindfulness practice and in life in general (Hölzel et al, 2011). Additionally, while focusing on the breath or other objects of internal experience a person may increase their body awareness as a result of such mindfulness application. Mindfulness is generally linked with ER improvements and strategies such as reappraisal (e.g., reconstruing a past negative event as meaningful or beneficial). However, the precise nature of this
connection is doubtful, as various studies have shown both greater and lesser cognitive control and prefrontal activation in participants while utilizing mindfulness, with differences depending on factors such as meditation expertise. Lastly, changes in perspective on the self may relate to insights gained from using mindfulness, including enhanced awareness and clarity of thought and the perspective of the self as part of ongoing mental activity that differs from moment to moment (Hölzel et al., 2011).

**Meditation: A Mindfulness Practice**

As described by Baer (2003), mindfulness and meditation relate to each other in numerous ways. For example, mindfulness not only originated from meditative practice but is developed through various meditation trainings. Akin to mindfulness, meditation is concerned with the voluntary and intentional regulation of one's attention in current experience. Furthermore, it is consistent among divers meditation practices, like with many mindfulness practices, to promote the selection of attention on internal bodily and mental events such as breathing, emotions, and thoughts, and to external events such as sounds and sights (Baer, 2003). In fact, one of the most highly cited methods of mindfulness training, mindfulness-based stress reduction (MBSR), employs body-sweeping meditation, mindfulness meditation, and hatha yoga (Kabat-Zinn, 1982).

Van Dam et al. (2018a) state that much confusion regarding mindfulness and meditation may emanate from undifferentiated usages of the words *meditation* and *mindfulness*, and this is an observation that could be understood in that these concepts share many similarities. Vago and Silbersweig (2012) concur with this view, stating that mindfulness can be viewed as a process, trait, state, and intervention, and has been obfuscated with various interpretations including that of meditation practice.

As the experiment described in this paper will not implement more than one form of meditation, this paper will not in-depth examine a plethora of meditation types. Thus, although researchers (e.g. Ospina et al., 2007) have identified types of meditation such as Qi Gong, Tai Chi, Vipassana, and Zen Buddhist meditation, these will not be examined comprehensively in this paper.
Jon Kabat-Zinn is one of the most frequently cited figures on what mindfulness is (Van Dam et al., 2018a), and has been referred to in the context of how mindfulness can be used in meditative practice (e.g., Baer, 2003). Kabat-Zinn (1982) defines two types of meditation: mindfulness meditation and concentration meditation. Attention is restricted to a single point or object in concentration meditation, whereas mindfulness meditation pertains to attention being maintained steadily without a specific target and expands from a focus on breath to encompassing all physical and mental events (Kabat-Zinn, 1982). Mindfulness meditation has also been defined as a non-judgemental attention to current experiences (Tang, Hölzel, & Posner, 2015) and as a regulatory attention training (Allen et al., 2012). Broadly, Kabat-Zinn (1982) refers to meditation as “the intentional self-regulation of attention from moment to moment […] It is neither contemplation nor rumination” (p. 34).

However, other researchers discriminate between focused attention (FA) meditation and open monitoring (OM) meditation, with similar distinctions as between concentration and mindfulness meditation respectively (e.g., Lutz, Jha, Dunne, & Saron, 2015; Lutz, Slagter, Dunne, & Davidson, 2008; Raffone & Srinivasan, 2010; Travis & Shear, 2010). Some researchers (e.g., Nash & Newberg, 2013) use terms such as OM meditation and mindfulness meditation interchangeably, while others (e.g., Fujino, Ueda, Mizuhara, Saiki, & Nomura, 2018; Tang et al, 2015) state that mindfulness meditation can be divided into methods relating to FA and OM. Sperduti, Martinelli, and Piolino (2012) describe that schools of meditation can be categorized on a continuum between FA and OM techniques, and that many use both of these practices harmoniously.

Meditation encompasses core aspects such as emotional responsiveness, embodiment, and silence (Kabat-Zinn, 2003). Moreover, mindfulness meditation may promote further valuing of low-arousal positive states such as calmness or peacefulness (Galante, Galante, Bekkers, & Gallacher, 2014). Thus, when taking into account the characteristics of both mindfulness and meditation, it appears these practices relate to attention and can be used separately or combined to create SR
processes. As related by Tang et al. (2015), mindfulness meditation consists minimally of three components that may be said to form an associated process of SR: (a) changed self-awareness (e.g., increased body-awareness, decreased self-referential processing), (b) improved ER, and (c) facilitated attentional control.

**Criticism on Mindfulness-Related Research**

Some researchers (e.g., Chiesa & Malinowski, 2011; Van Dam et al., 2018a) have criticized mindfulness research in general. Van Dam et al. (2018a) state that the term *mindfulness* carries differing meanings depending on the researcher and context: a reflection of the popularity of the concept. As a result, theoretical views on mindfulness vary and the concept may refer to attention, memory, acceptance, Buddhist or meditation practice, or even intervention packages such as MBSR (Lutz et al., 2015; Vago & Silbersweig, 2012; Van Dam et al., 2018a).

Criticism has also been levied against scientific research on meditation, stating there exists no shared theoretical perspective and that the methodological quality is low (e.g., Nash & Newberg, 2013; Ospina et al., 2007; Van Dam et al., 2018a).

In addition, individuals may exhibit different effects from the same meditation practices, including adverse effects such as increases in depression, anxiety, awareness of negative emotions, and psychosis (Farias & Wikholm, 2016). The literature on harm in these contexts is limited, and negative meditation effects occur more commonly in intensive retreat settings (Baer, Crane, Miller, & Kuyken, in press). Adverse meditation experiences may occur at rates between 5 and 30% of meditation sessions depending on time frame and sample (Van Dam et al., 2018b). One study discovered that, while psychological stress decreased, salivary cortisol increased after mindfulness meditation (Creswell, Pacilio, Lindsay, & Brown, 2014). This could be explained by greater coping efforts among these participants, as other studies have displayed analogous results (Creswell et al., 2014).

Davidson and Dahl (2018) have responded to some meditation-related criticisms. For example, similar methodological issues as described by Van Dam et al. (2018a) have been a topic of
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discussion for psychologists on issues concerning emotion constructs such as anxiety. That is, similar terms may be used by researchers for different states or contents of mind, and it is thus recommended that one specifies operational definitions when measuring psychological constructs (Davidson & Dahl, 2018). Furthermore, meditation practices have as a prominent focus the well-being of humans, and their use in clinical or disease-treatment settings is a relatively recent development (Davidson & Dahl, 2018).

Imprecise or varying usages of the word meditation is discussed by Lutz, Dunne, and Davidson (2007). Intellectual movements, such as perennialism, may pose a problem for neuroscience because ideas that surpass reason, perception, or language could be unverifiable (Lutz et al., 2007). Moreover, unspecific uses of terms such as meditation trivializes the practice itself and can lead to a failure to detect underlying processes engaging different neural circuitry (Lutz et al., 2007).

Nash and Newberg (2013) state that the lack of unified meditation definitions can be seen in that there are two opposing viewpoints on what meditation is within the scientific literature. From one perspective meditation may be categorized as a group of mental training techniques, and from another regarded as experiential or altered states of consciousness derived from the same methods (Nash & Newberg, 2013). In this paper, the perspective concerning mental training will be used as a foundation.

Based on the dichotomy of the mental training and altered state definitions of meditation, Nash and Newberg (2013) propound a definitional model that regards meditation as a dynamic process of six stages. The first stage, normal, occurs before and after meditation and is the waking or resting state associated with the default mode network (DMN). The second stage, intention to begin, is described as crucial in the sense that volition is required for a person to engage in the meditative process. The third stage, preliminaries, relates to preparation where a person might assume a position for meditation. The fourth stage, method, consists in the practices or procedures of meditation (e.g., FA, OM). The fifth stage, enhanced mental state, is the causal result of the
method, and might relate to increases in concentration, calm, well-being, and so forth. Lastly, the sixth stage, \textit{intention to finish}, comprises the individual's choice to stop meditating and return to their baseline state of consciousness (Nash & Newberg, 2013).

\textbf{Beneficial Effects of Mindfulness and Meditation}

As potential support of the regulatory aspect or outcome of mindfulness, individuals who score highly in the Mindful Attention Awareness Scale are less likely to be socially anxious or ruminate, and more likely to fulfil basic psychological needs (Brown & Ryan, 2003). Accordingly, this may indicate that mindfulness is linked in some sense to peaceful or low-affect states of mind. In truth, mindfulness training has been demonstrated to enhance inner peace without being mediated by changes in self-rated mindfulness (Liu et al., 2015). Other research has displayed positive correlations between mindfulness and peace of mind (Xu, Rodriguez, Zhang, & Liu, 2015).

Feldman, Greeson, and Senville (2010) compared the effect of loving-kindness meditation, progressive muscle relaxation, and mindful breathing on decentering. In their research, the mindful breathing condition increased decentering more than the other conditions both when measured as a correlation between the frequency of and emotional reactions to repetitive thought and through a self-report scale. These results may indicate that decentered perspectives can increase awareness of repetitive thought and decrease the prevalence of repetitive thought via mechanisms such as emotional processing and habituation (Feldman, Greeson, & Senville, 2010).

Furthermore, mindfulness interventions have been associated with reductions in anxiety, depression, burnout, anger, stress, and distress, and with increases in satisfaction, compassion, ER, and health, among other factors (Greeson, 2009; Lomas et al., 2017). Mindfulness practice can reduce bottom-up processing of cues (e.g., craving and stress; McConnel & Froeliger, 2015), and may be able to increase inhibitory control of negative emotions (Garland et al., in press). Mindfulness is associated with improved executive cognitive functions such as working memory, attentional control, and sustained attention (Chambers, Gullone, & Allen, 2009). One study also reported that mindfulness may improve the SR skills of youths, improving their ability to meet
school demands, decreasing anxiety, and so forth (Zelazo & Lyons, 2012).

Meta-analyses and reviews on mindfulness meditation procedures have displayed reductions in depression, stress, pain, anxiety, substance-abuse, and fibromyalgia, and benefits in well-being, executive functioning, and ER (Eberth & Sedlmeier, 2012; Gallant, 2016; Goyal et al., 2014; Tang et al., 2015; Toneatto & Nguyen, 2007). One meta-analysis calculated a total effect size of mindfulness meditation in 39 studies at 0.56, which indicates that meditation benefits are not due to chance (Eberth & Sedlmeier, 2012). A clinical trial utilizing various meditation procedures, including Hatha yoga and body scan meditation, found improvements in stress, trait and state anxiety, indicators of psychopathology, and sleep quality (Biegel, Brown, Shapiro, & Schubert, 2009). The benefits of meditation are on average comparable in impact to those of psychotherapy or behavioral treatments (Sedlmeier et al., 2012).

Breathing is a prominent element in the majority of meditative practices and is closely connected to mental processes (Zaccaro et al., 2018). A review by Zaccaro et al. (2018) indicates that slow breathing techniques recruit the parasympathetic nervous system, as suggested by increases in respiratory sinus arrhythmia and heart-rate variability. Other outcomes of slow breathing includes increased blood-oxygen-level dependent activity in areas of the brain such as the thalamus and hypothalamus, the pons, and the parietal, motor, and prefrontal cortices (Critchley et al., 2015). Slow breathing appears to promote the parasympathetic nervous system while being mediated by vagal activity, enhance psychological, cerebral, and autonomic interactions, and can increase well-being and emotional control (Zaccaro et al., 2018). Ditto, Edache, and Goldman (2006) found similarly that meditation compared to relaxation increased parasympathetic activity. As such, one may infer that the breathing component of meditative practices accounts for some of their benefits.

The Neural Correlates of Mindfulness

The neuroscience of mindfulness can be considered an interdisciplinary field combining neuroscientific research with mindfulness practice (Tang & Posner, 2013). In this field there is an
overlap between various measures and techniques such as neuroimaging, behavioral tests, mindfulness-based meditation, and mindfulness-based intervention (Tang & Posner, 2013).

**Functional Magnetic Resonance Imaging (fMRI)**

There are numerous studies that have employed fMRI to examine neural correlates related to mindfulness and types of meditation.

In one study, Westbrook et al. (2011) trained participants to view and rate smoking and neutral images using mindful attention or by being passive. The mindful attention group had decreased neural activity in the subgenual anterior cingulate cortex (ACC); a region associated with craving. The mindful attention group also displayed reduced craving via self-report. Thus, by reducing craving to smoking cues mindfulness may promote smoking cessation (Westbrook et al., 2011). Although self-reporting of craving may have limited predictive power, there is much support for the connection between drug usage and craving of drugs (Westbrook et al., 2011).

The study by Westbrook et al. (2011) could be confounded, anyhow, due to the strong desire to stop smoking expressed by the participants. That is, even if the desire to quit smoking was controlled by allocating participants to the different groups, since all participants wanted strongly to quit smoking they might not represent the general population of smokers. In contrast, Westbrook et al. (2011) controlled for many variables (e.g., medication, brain injury, mental disorder, smoking before brain scanning), and this increases confidence in the results.

In a study implementing mindful breathing to achieve a non-judgmental concentration, Hölsel et al. (2007) report that participants had increased rostral ACC and dorsal medial prefrontal cortex (MPFC) activation. This could be explained by increased processing of emotional conflict during mindfulness and improved ER as reflected by increased emotion processing, respectively (Hölzel et al., 2007).

Mindfulness was compared with a mental arithmetic task, but the mindfulness condition lasted twice as long (1 min) as the arithmetic task (Hölzel et al., 2007). Additionally, the increased cerebral hemodynamic response observed for meditators over controls is not necessarily explained
by greater mindfulness, since groups were not randomized but self-selected (directionality problem).

Dispositional mindfulness was associated with increased PFC and decreased amygdala activity in an affect labelling task (Creswell, Way, Eisenberger, & Lieberman, 2007). While assigning emotions (e.g., scared, angry) to facial expressions, it is thus possible that greater mindfulness augments the neural regulation of affect-related areas such as limbic regions (Creswell et al., 2007).

Jang et al. (2011) conducted an fMRI study comparing controls to meditators who focused their attention on their emotions and bodily sensations. Meditators had increased MPFC activity, and this is an area with connections to exteroceptive and interoceptive modalities (Jang et al., 2011).

Garrison, Zeffiro, Scheinost, Constable, and Brewer (2015) instructed participants in an fMRI study in one of three different meditation methods: (1) to concentrate on their breath, (2) to adopt a loving-kindness perspective and repeat positive mantras, and (3) to monitor their experiences without any explicit focus. The results for these different conditions appeared to have been amalgamated by Garrison et al. (2015) and were compared to a cognitive task where participants judged adjectives.

In the study, mindfulness practice was linked to decreased activity in the ventral precuneus, ACC, posterior cingulate cortex (PCC), and middle temporal gyrus, and with increased activity in the bilateral rectal gyrus and orbitofrontal cortex when compared to the cognitive task (Garrison et al., 2015). The aforementioned areas associated with the DMN also displayed lower activity in meditators during rest. Finally, functional connectivity in parts of the DMN appears to generally have differed between meditators and controls. However, none of these results were differentiated for the three meditation methods implemented. Garrison et al. (2015) state that the results could imply differences in both DMN resting-state and active-state processing, and in the behavioral state of individuals in the resting state. For example, analogous decreases in activation of the PCC were connected to reports of decreased mind-wandering and increased focused attention in meditators in
an fMRI study by Garrison et al. (2013).

When compared to individuals without prior mindfulness experience, mindfulness practitioners have displayed significant activity reductions in the MPFC as well as increased activity in the insular cortex (IC), second somatosensory cortex, and right lateral PFC (Farb et al., 2007). These findings may support the idea that, with mindfulness training, narrative self-focus is less likely to occur in the presence of momentary self-focus, whereas people who do not engage in intentional mindfulness practice are more likely to engage narrative self-focus and momentary self-focus concurrently. In other words, the two forms of self-awareness may be dissociated through attention training (Farb et al., 2007). The specific training used by Farb et al. (2007) for their fMRI study was packaged in a MBSR program where participants trained daily in focusing attention on the present moment.

Brewer et al. (2011) investigated neural patterns via fMRI across meditation practices concerning concentration, loving-kindness, and choiceless awareness. It was discovered that these different ways of being mindful each, when contrasted with controls, displayed decreased activation in the MPFC and the PCC; two predominant areas of the DMN associated with mind-wandering, self-related thought, and evaluating one's emotional states (Brewer et al., 2011). These results may be explained by the roles of mindfulness-based practices in orienting the mind away from wandering, self-reference, and identifying with experiences (Brewer et al., 2011).

However, the study sample was somewhat small and consisted in only highly experienced meditators. Thus, such results are not necessarily generalizable to larger and less experienced populations. But there was convergent validity in that all three meditation methods had similar results (Brewer et al., 2011), and that increases confidence in the results.

Another fMRI study found that experienced compared to novice meditators had decreased activation in brain regions associated with sustained attention at 44.000 hours of experience but not at 19.000 hours (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007). This may imply that brain plasticity is involved (Brefczynski-Lewis et al., 2007): an interpretation that Hasenkamp
and Barsalou (2012) arrived at likewise when studying meditation effects on attention.

Furthermore, Hasenkamp and Barsalou (2012) distinguished neural patterns during FA meditation depending on different cognitive activation. For example, sustained attention was associated with executive brain networks, and awareness of mind wandering with the salience network (Hasenkamp & Barsalou, 2012). In their study, Hasenkamp and Barsalou instructed participants to focus on the sensations of the breath on the nostrils and upper lip. This is different from many other general mindful breathing instructions (e.g., Feldman et al., 2010; Garrison et al., 2015; Hölzel et al., 2007), but not necessarily confounding because it might still achieve the same or a similar present-moment attention.

Allen et al. (2012) produced data indicating that mindfulness meditation improved executive neural processing and cognitive control as measured by a Stroop task. In the same study it was further observed that blood oxygen level-dependent activity in areas such as the dorsal lateral PFC (DLPFC) and dorsal ACC increased. Allen et al. (2012) forward two explanations for this data: (a) that it underlies increased FA in novices, and (b) that it reflects an accentuated open-mindedness and sensitivity to affect in participants with higher practice adherence.

The study by Allen et al. (2012) had a sample size of 60, which is larger than many studies on meditation. Through exclusion criteria, possible confounding variables such as prior meditation experience, mental disorders, drugs and recreational substances, and age were controlled for. The mindfulness meditation practice included a focus on breath, body-scanning, a compassionate perspective, and an open-monitoring method designed to unify all of these elements (Allen et al., 2012).

The instructions were inspired by MBSR programs and insight meditation traditions such as Vipassana (Allen et al., 2012). These varying aspects of the meditation potentially confound its effect. It is not clear if compassion or Vipassana practice during a monitoring of the present moment facilitates attention, if they synergize, or if other effects emerge from these various elements. And since Allen et al. (2012) do not clarify how the differing elements together form the mindfulness
meditation method, one can not know how the described methods were delivered to participants other than by the guidance of experienced instructors.

Manna et al. (2010) explored differences between six minutes of Samatha (FA) and Vipassana (OM) meditation and rest. Groups were comprised of eight experienced (15,000 hours) and eight novice meditators, and meditation instructions were written by a meditation expert from a monastery. In the experiment, all participants meditated based on FA and then OM instructions, with breaks (3 min) before and after. This was repeated three times (Manna et al., 2010).

Overall, FA and OM meditation were associated with dissociable brain systems concerning selective attention, conflict monitoring, and sustained attention (Manna et al., 2010). For instance, FA was related to increased ACC and decreased PCC activity. And OM was associated with lateral PFC activity compared to the FA condition, and with precuneus activation compared to both rest and FA. For many of the contrasts, activation was discovered in the left but not right hemisphere (Manna et al., 2010).

The religious elements in the study by Manna et al. (2010), such as the reliance on aspects of the Buddhist school of Theravada, could be criticized as imparting a kind of bias onto the study. At the same time, it appears the FA and OM meditation methods were not out of the ordinary and that the pauses used could have decreased sequence effects. The sample was very small, however.

A recent study indicated that FA and OM meditation may decrease functional connectivity in regions linked to mind-wandering (e.g., areas of the DMN such as the PCC; Fujino et al., 2018). But whereas FA meditation increased connectivity in attention areas, OM meditation decreased connectivity in these same regions (e.g., the visual cortex). As such, there may be attention-regulation differences between OM and FA meditation (Fujino et al., 2018). The sample size was low (n=17), but the within-subject design decreases this issue to some extent.

Jang et al. (2011) coordinated a study comparing 35 experienced meditators with 33 participants that had no experience with meditation or similar practices. An increased connectivity in the anterior MPFC was discovered for meditators. This connectivity may derive from the brain's
neuronal plasticity, as a result of a meditation practice that asks participants to concentrate on their emotions and bodily experiences as they move with natural, rhythmic motions. Nevertheless, the study is limited in its conclusions since the design was cross-sectional. Thus, it is uncertain whether the meditation increased MPFC connectivity, or if the groups differed on this variable for other reasons. For example, the part of the population that chooses to meditate may already differ from the general population (Jang et al., 2011).

Jang et al. (2011) discuss changes in the MPFC after meditation, stating that it is an area linked with interoceptive and exteroceptive modalities. According to Jang et al. (2011), the MPFC is activated by mental simulations regarding the self. Moreover, several findings from the wider literature seem to reinforce the idea that the reduced mental activity observed in connection to meditation is mediated by activation in brain networks supporting internal attention (Jang et al., 2011).

Mindfulness may incorporate methods of sustaining attention to interoceptive information (e.g., the breath; Farb, Segal, & Anderson, 2013). For this reason, Farb et al. (2013) contrasted an eight-week MBSR group to a wait-list control group to study the effects of mindfulness training on interoceptive attention. In the experiment, the two groups were compared while engaging in interoceptive (monitoring of the breath) and exteroceptive (reading words or pressing keys based on sights) attention tasks. In comparison to controls, MBSR participants had increased recruitment of the posterior IC and decreased MPFC activity corresponding to the mindfulness goal (Farb et al., 2013).

There are several possible extraneous variables in the study. Some parts of the MBSR course were not connected to mindfulness or meditation (i.e., stress management education and diary writing). And a large portion of the participants reporting being highly stressed and experiencing negative emotions (Farb et al., 2013).

As many meditation studies compare experienced meditators to novices, Dickenson, Berkman, Arch, and Lieberman (2012) wished to investigate which neural systems support
mindfulness meditation in those without notable amounts of meditation practice. Comparing focused to unfocused attention groups, Dickenson et al. (2012) found significant activation in regions involved with attentional control such as the temporal-parietal junction and superior parietal lobule. Areas believed to mediate attention to response selection and sensory information, such as the dorsal ACC, were also recruited. Additionally, regions such as the insula and hippocampus displayed increased activation. Finally, unfocused attention was associated with activation in regions related to the DMN while focused attention was conversely related to the same areas. Dickenson et al. (2012) suggest that, since trait mindfulness measures were correlated with activity in attention areas, this may imply that brain systems associated with mindfulness are meaningfully related to each other outside of experimental settings.

Other Methods of Measuring Brain Activity

Using electroencephalography, a study found that dispositional mindfulness might decrease the amplitude of the late positive potential: a neural marker of ER (Brown, Goodman, & Inzlicht, 2013). Based on highlighted research on the late positive potential by Brown et al. (2013), it appears it is an indicator of attention to emotional stimuli and emotional arousal. Thus, the late positive potential seems an appropriate tool for measuring how mindfulness can affect ER.

The effect of a meditation practice centred on mindfulness was tested with thermal pain training (Grant, Courtemanche, Duerden, Duncan, & Rainville, 2010). Grant et al. (2010) discovered that meditators had decreased pain sensitivity when compared to controls, and this was linked with thicker cortex in pain and affect-related areas such as the anterior IC and ACC seen via MRI.

From a study employing diffusion tensor imaging (DTI) alongside MRI, it has been uncovered that experienced mindfulness practitioners using FA methods (e.g., mantras, mindful-breathing, monitoring of the body) have greater fractional anisotropy in the anterior corpus callosum, which might be linked to the ability to regulate the fluctuations of the mind (Luders et al., 2012).
The study design of Luders et al. (2012) could be criticized since participants of the experimental group had variance in their meditative traditions. Can you treat participants influenced by Kriya, Vipassana, and Chenrezig practices all as one group, or would that perhaps be an oversimplification? The relatively moderate sample size (n=30) and high amount of average meditative experience (20 years) further decreases the likelihood that the results generalize outside of the study sample.

**Indirect Studies on Neural Networks**

Although studies with attention tasks by themselves do not examine neural changes, they could still be related to activation in brain areas. That is, if said attention tasks, for instance the ANT, are theorized in relation to brain networks in their foundation.

In a study using meditation retreats and methods such as FA, loving-kindness, and mindful breathing, executive attention but not orienting attention was improved (Elliott, Wallace, & Giesbrecht, 2014).

Another study implementing 10 minutes of mindfulness meditation training concluded that participants benefited from the meditation in terms of improved attentional resource allocation, based on ANT accuracy and reaction time results (Norris, Creem, Hendler, & Kober, 2018). However, in this study participants were rewarded by a chance to earn one of two 25-dollar prizes in a lottery (Norris et al., 2018). Moreover, the meditation was guided as participants listened to audio-tapes, but whether participants followed the instructions delivered through the tape was not verified (although it may be inferred from the attention results).

Jha et al. (2007) contrasted meditation retreat and MBSR groups with controls. Meditation involving concentration was connected to improvements in executive and orienting attention, which Jha et al. (2007) state may reflect changes in the dorsal attention system. More experienced concentration meditators also displayed greater alerting attention than the other groups (Jha et al., 2007). Both meditation groups employed sitting and walking meditation, although receptive attention practice similar to OM meditation was included for the MBSR group during the fifth
The amount of meditation differed radically between the groups, with the retreat group meditating up to 12 hours per day.

Srinivasan and Singh (2017) report that FA meditation can increase the perceived duration and sharpness of afterimages. This could suggest that improved attentional focus can affect phenomenal experiences in visual awareness (Srinivasan & Singh, 2017). But the quality of this study is questionable, as the sample size was low (n=25) and the meditators were teachers of Sahaj Samadhi meditation. It could be argued that this meditation tradition contains many typical mindfulness and meditation elements (e.g., present-moment awareness, mantra recitation), but one could equally state that the sample may not be generalizable to general mindfulness or meditation populations due to aspects such as the heavy spiritual connotation of Sahaj Samadhi.

Moore and Malinowski (2009) conducted a study comparing Buddhist meditators to a matched control group. Mindfulness meditation improved attention, such as by decreasing Stroop interference. Some of the attention improvements might reflect the ability of the meditators to focus attention and sustain said focus over time (Moore & Malinowski, 2009). The meditators were described as experienced in mindfulness meditation, but which instructions or method they followed was not detailed and decreases replicability. Moore and Malinowski (2009) controlled for sleep prior to participation, and noise during participation.

**Neural Correlates From a Broader Perspective**

Singular articles may point in one or another direction and contradict each other, but review articles can illuminate commonalities across a broader range of research to limit such issues.

**Review articles.** Cahn and Polich (2006) reviewed meditation practices involving aspects such as mindfulness or FA (e.g., with the breath as focus). A variety of meditation traditions and research designs were included in the review, and Cahn and Polich (2006) attribute part of the divergence in results to these aspects. Meditation practice generally increases attentional resources and ACC and prefrontal brain areas appear to be recruited (Cahn & Polich, 2006).

According to Tang and Posner (2013), several studies have used cortical thickness mapping
and diffusion tensor imaging to explore the long-term effects of meditation on brain structure. In these studies, meditators have displayed significantly greater cortical thickness compared to controls in the anterior regions of the brain including the MPFC, superior frontal cortex, temporal pole, and the middle and interior temporal cortices. Moreover, reductions in cortical thickness were found in the posterior regions of the brain including the postcentral cortex, inferior parietal cortex, middle occipital cortex, and PCC. Lastly, in the region adjacent to the MPFC, both higher fractional anisotropy values and greater cortical thickness have been observed (Tang & Posner, 2013).

One interpretation of this data is that thinner cortical thickness of brain regions in meditators, including the lateral and medial parietal areas, can be explained as influenced by the enhancement of cognitive functions such as improved attention and self-perception (Kang et al., 2012). The increase in cortical thickness in frontal and temporal areas may be elucidated by reference to emotion processing. For instance, previous research has reported beneficial effects of meditation on ER, and the MPFC is involved in ER (Kang et al., 2012). Note that the article by Kang et al. (2012) is not a review article, but was referenced here to explain results not elucidated but referred to by Tang and Posner (2013).

McConnell and Froeliger (2015) compared mindfulness mechanisms to addiction research. There is evidence that mindfulness practice is associated with activation in the striatum, amygdala, and frontolimbic and frontostriatal MPFC: areas that have been described as related to affect and ER (McConnell & Froeliger, 2015).

One common thesis to describe how mindfulness meditation can influence ER is the idea that prefrontal cognitive control mechanisms are facilitated to downregulate affect-processing in areas such as the amygdala (Tang et al., 2015). Results regarding regions such as the anterior IC, thalamus, and orbitofrontal cortex, and mechanisms such as nociceptive and pain processing, appear to support the thesis that mindfulness meditation can improve ER (Tang et al., 2015).

Meditation practices are regularly accompanied by an emphasis on attention-regulation as a necessary component, and on attentional control as a core aspect (Tang et al., 2015). The ACC and
DLPFC have continually been linked with mindfulness meditation effects on attention (Tang et al., 2015).

In an overview by Chiesa et al. (2011), meditative practices containing mindfulness compared to controls were associated with executive attention improvements in nine studies. For example, van den Hurk, Giommi, Gielen, Speckens, and Barendregt (2010) discovered improvements in orienting and executive attention for mindfulness meditators. And for participants on a MBSR course implementing meditation practices such as body scan meditation and mindful breathing, mindfulness was associated with non-directed attention but not attentional control (Anderson, Lau, Segal, & Bishop, 2007). There was high variation in study design and positive results were commonly displayed in case-control studies (Chiesa et al., 2011). Therefore, the conclusions of the overview should be considered with caution to an extent.

Gallant (2016) conducted a systematic review of the connection between mindfulness practice (primarily mindfulness meditation) and aspects of executive functioning. Mindfulness practices may improve executive functioning components such as inhibition. Gallant (2016) underlines that several mindfulness studies have documented alterations in areas important for executive functions (e.g., the ACC).

Lutz et al. (2008) state that effects of OM meditation can be understood from a global perspective, where moment-to-moment processing is affected by a changed default mode functioning. However, these mechanisms are predictions that currently lack much empirical support. Further, there is speculation that, since OM meditation has no direct attentional focus, it should not have to depend on brain areas connected to sustaining attention on specific objects but on areas involved in monitoring and disengaging attention from distractions (Lutz et al., 2008).

In their review, Wheeler et al. (2017) state that research indicates that individuals high in dispositional mindfulness have increased grey matter volume in areas of the amygdala and IC, which is associated with greater emotional control. Furthermore, greater dispositional mindfulness is connected to activation in regions of the PFC such as the DLPFC (Wheeler et al., 2017).
Wheeler et al. (2017) additionally review the relation of mindfulness to the DMN: the brain at rest. The DMN is related to present-moment self-related processing (e.g., interoception) and narrative self-related processing (e.g., episodic memory). Whereas rumination and mind-wandering have been connected to narrative self-related processing, mindfulness has been related to present-moment self-related processing. Brain areas such as the right somatosensory cortex, IC, and MPFC have been associated with present-moment self-related processing (Wheeler et al., 2017).

This perspective is supported by other researchers. For example, Jang et al. (2011) state that brain regions associated with mindfulness practice (e.g., meditation) are notably alike those that have been connected to the DMN. Areas continually activated during stimulus-independent thoughts (e.g., reflective and self-referential thoughts) believed to be part of the DMN include the lateral temporal cortex, inferior parietal cortex, PCC, ACC, and MPFC (Jang et al., 2011).

Vago and Silbersweig (2012) have connected the mechanisms of attention, SR, and ER in the context of mindfulness practice, stating that there is overlap between self- and emotion-regulation and that they, in general, refer to the ability to modulate emotional activity and attentional focus. Thus, brain areas (e.g., the DLPFC and ACC) that have by other researchers (e.g., Tang et al., 2015) been related to attention, are also linked to ER by Vago and Silbersweig (2012). Furthermore, Vago and Silbersweig (2012) describe that mindfulness practices (e.g., types of meditation) can affect other regulatory functions such as stress and homeostasis by, for instance, reducing hypothalamic-pituitary-adrenal axis activity. For example, various meditation studies have affected aspects such as cortisol, oxygen consumption, and blood pressure, and displayed reduced sympathetic and increased parasympathetic nervous system activity (Vago & Silbersweig, 2012).

Moreover, Vago and Silbersweig (2012) proposed a framework focusing on self-awareness, -regulation, and -transcendence (S-ART) to better understand mindfulness and its neural correlates. The elements of S-ART are based on brain networks relating to self-processing. Self-processing is further divided by Vago and Silbersweig, as inspired by other research, into three terms based on characteristics of self-processing concerning agency and consciousness (e.g., self-reflection and
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sensory-affective-motor processing): (a) the enactive experiential self (EES), (b) the experiential phenomenological self (EPS), and (c) the evaluative narrative self (NS; Vago & Silbersweig, 2012).

The EES concerns non-conscious neural activity and has been associated with areas of the brain such as the posterior IC, thalamus and hypothalamus, and midbrain colliculi, which are regions involved in interoceptive feedback (Vago & Silbersweig, 2012). The EES is also connected to networks regarding preparatory behavior and action selection, such as the pre-motor area, cerebellum, and ventral lateral PFC (Vago & Silbersweig, 2012).

The EPS relates to self-specifying experience in which there exists awareness that can be affected by cognition (Vago & Silbersweig, 2012). The EPS is linked with attentional networks and functions such as top-down processing, and is thought to construct higher order experience such as affective, motivational, and social feelings. Areas that are believed to be important for the EPS include the dorsal ACC, temporo-parietal junction, and the right DLPFC. Studies have indicated that the anterior IC has a role in states associated with the EPS, and that its activity is inversely correlated to areas connected with the NS such as the PCC and posteromedial cortex (Vago & Silbersweig, 2012).

Lastly, the NS concerns a form of metacognitive knowledge and reflective identification of the self via narratives. The NS is linked with the hippocampal-cortical memory system and, consequently, brain structures such as the amygdala, medial parietal cortex, and areas of the cingulate cortex. The NS has been related to task-negative networks (Vago & Silbersweig, 2012). The DNM, a task-negative network, is associated with mind-wandering and thought processes (Hasenkamp & Barsalou, 2012), which is similar to what the NS relates to.

Conversely, present-moment and attention processes are, in parallel with the EES and EPS, related to task-positive networks (Hasenkamp & Barsalou, 2012). Present-moment processing has, moreover, been linked with the salience network: a network that involves the anterior IC and dorsal ACC (Seeley et al., 2007). Another system, the frontoparietal control system, appears to integrate information from the networks associated with the NS, EES, and EPS, and its substrates (e.g., the
frontopolar cortex) facilitate meta-monitoring and might be imperative to SR and self-awareness (Vago & Silbersweig, 2012). Mindfulness intervention is reported to decrease NS activity and increase EPS and frontoparietal control system activity (Vago & Silbersweig, 2012).

Kerr, Sacchet, Lazar, Moore, and Jones (2013) proposed a framework of neural mechanisms to illuminate the effects of standardized mindfulness training (e.g., MBSR). Kerr et al. (2013) describe that, based on conventional mindfulness components (e.g., present-moment attention, awareness of mind-wandering), mindfulness training might be reflected at the neural level in brain alterations concerning signal-to-noise ratio in sensory-attentional processing.

More precisely, the body-focused attention of mindfulness might enhance the 7-14 Hz alpha rhythm believed to be implicated in regulating sensory input (Kerr et al., 2013). There are some preliminary studies that appear to support the framework of Kerr et al. (2013), but few of the neural functions connected to mindfulness in their overview are thoroughly studied.

**Meta-Analyses.** Reviews have their place in synthesizing data and inferring conclusions from a broader perspective. However, it requires a meta-analysis to statistically analyse such commonalities and display their significance.

One meta-analysis attempted to locate similarities in brain activation across dissimilar meditation practices (Sperduti et al., 2012). Based on 10 neuroimaging studies involving both OM and FA meditation practices, there was prominent activation in the MPFC, caudate nucleus, and enthorinal cortex. Sperduti et al. (2012) discuss these results by, for instance, mentioning the high involvement of the enthorinal cortex in ER and the potential role of the striatum in response inhibition, ER, and attention processes.

The 10 analyzed studies had a total of 91 participants, which means the average sample size was very small. Sperduti et al. (2012) did not appear to account for any differences in the meditative traditions they collected under the labels FA and OM aside from noting that practices such as Yoga (e.g., Kundalini) and Tantra meditation were included. This may confound the results.

In a meta-analysis by Fox et al. (2014), eight brain regions were routinely associated with
change in meditators over 21 morphometric studies: (a) the frontopolar cortex, (b) the sensory cortices and IC, (c) the hippocampus, (d) the ACC, (e) the mid-cingulate cortex, (f) the orbitofrontal cortex, (g) the superior longitudinal fasciculus, and (h) the corpus callosum. Meditation types from the analyzed studies included concentration, OM, and mindfulness methods.

The results can be interpreted as revealing that mindfulness meditation possibly activates brain areas that, for example, relate to memory, hemispherical communication, ER, cognitive awareness, and body awareness. A medium (d=.46) effect size was calculated for 16 of the studies (Fox et al., 2014), and may indicate that the observed brain changes are non-trivial.

Nonetheless, it should be noted that the meta-analysis by Fox et al. (2014) encompassed a multitude of meditation practices (e.g., Zen, Soham, and insight meditation) and that data were collapsed across these practices. Another possible issue with the meta-analysis is that data from different morphometric neuroimaging techniques were compared. Fox et al. (2014) state, nevertheless, that there is preliminary evidence for the validity of such comparisons.

Structural changes were discovered in several brain regions in the meta-analysis, with significance depending on the selected thresholds (Fox et al., 2014). As with many previous studies, meditation affected the IC. The structural changes of the IC may be due to its implication in interoception and, tentatively, its function in metacognitive awareness and emotional self-awareness. Further, the primary and secondary somatomotor cortices were affected, which may be from the body-awareness focus of some the types of meditation analyzed. Other areas, such as ones relating to instrospection (the rostrolateral PFC), SR and ER (e.g., the ACC and orbitofrontal cortex), and spatial processing (the superior longitudinal fasciculus), also exhibited structural gray or white-matter changes (Fox et al., 2014).

Fox et al. (2016) presented a meta-analysis that differentiated between meditation types such as FA and OM meditation. Studies included utilized fMRI and positron emission tomography (Fox et al., 2016). Meditation traditions were various (Vipassana, Tibetan Buddhist, Theravada) but grouped together into categories based on their instructions. Loving-kindness and compassion
meditation studies were analyzed by Fox et al. (2016) but are omitted from this paper in favour of focusing on FA and OM methods. A total of 25 studies were used in the analysis, and these were compared across different baseline and comparison groups which could be a confound (Fox et al., 2016).

FA meditation was associated with activation in areas of the PFC such as the dorsal ACC and premotor cortex (Fox et al., 2016). According to Fox et al. (2016) these brain areas are commonly connected to regulation in action, cognitive control, and self-reflection. Deactivation during FA meditation was observed in the left inferior parietal lobule and ventral PCC. These regions have been related to conceptual processing and episodic memory. Moreover, Fox et al. (2016) conclude that this is consistent with goals of FA meditation regarding decreases in mind-wandering and regulation demands of sustained attention. Fox et al. (2016) state that several areas (e.g., the dorsal ACC and areas of the PFC) were previously hypothesized by Lutz et al. (2008) to be involved in FA meditation and that the current analysis supported such hypotheses.

Mantra recitation meditation, which could be considered a kind of FA meditation, was associated with activation in parts of the motor control network (e.g., Broca's area, premotor cortex) and in the basal ganglia (i.e., the putamen and globus pallidus; Fox et al., 2016). The results can partly be explained in that Broca's area is linked with speech production and the parts of the basal ganglia with inhibiting undesired and facilitating desired movements. There was deactivation in regions relating to interoceptive (e.g., the IC) and auditory (e.g., the primary auditory cortex) information, which could be understood since particular kinds of FA might decrease awareness of some stimuli (Fox et al., 2016).

OM meditation was connected to activation in several areas, such as the premotor cortex, supplementary motor area, and the IC (Fox et al., 2016). As stated by Fox et al. (2016), these areas relate to interoceptive processing and voluntary control of action. Further, OM meditation was associated with significant deactivation in the right thalamus, which might reflect the OM meditation goal of openness (Fox et al., 2016). There were only small differences between
meditation practitioners with short- to long-term training, and the IC was active during all forms of meditation (Fox et al., 2016).

**Summary, Purpose, and Hypotheses**

To summarize, mindfulness and meditation generally concern the deployment of attention and awareness to experiences or events in the present moment in a non-judgemental and open-minded manner. Such a usage of the mind appears to be associated with neural alterations, including grey- and white-matter changes and increases and decreases in activation of brain areas such as the ACC, parts of the PFC (e.g., DLPFC, MPFC), the IC, and regions related to functions such as emotion, attention, and self-processing.

Based on such neural findings of mindfulness and associated practices such as mindfulness meditation, the aim of the present study was to employ an empirical investigation into the short-term effect of mindfulness meditation on negative affect and three forms of attention (alerting, orienting, and executive; e.g., Petersen & Posner, 2012). For this reason, an experiment with one experimental group and one control group was conducted. Attention was measured using the Attention Network Test (ANT) and negative affect with the Positive and Negative Affect Schedule (PANAS). PANAS was used since negative affect (e.g., distress, shame, fear) is a measure of aversive mood states that can be said to represent central features of ill-being such as anxiety and depression (Watson, Clark, & Tellegen, 1988). Consequently, this study did not aim to provide an investigation into the concept of ill-being but of the related component of negative affect.

In accordance with Monitor and Acceptance Theory (Lindsay & Creswell, 2017) and based on findings from the neuroscience of mindfulness and mindfulness meditation, it was hypothesized that mindfulness meditation would on average (a) decrease negative affect and (b) improve alerting, (c) orienting, and (d) executive attention when compared to a control condition.

**Method**

**Participants.** In the present study, convenience sampling was employed when selecting where to recruit. Recruiting occurred by inviting people to report their interest via e-mail. Contact
information was provided on a pamphlet that was hung on pinboards on the grounds of the University of Skövde. The paper briefly described background information of the study, how to become a participant, and basic information such as who the author and supervisor of the study are as well as the ethical guidelines the study followed. Programme coordinators responsible for programs at the University of Skövde were contacted and requested to share the same paper with students of the associated programs. A total of 17 programme coordinators were contacted, with four responding and sharing the recruitment paper to students of the first through third year of the Cognitive neuroscience – applied positive psychology programme and Public health programme, as well as to students of the Midwife and Social Psychology programmes of the University of Skövde.

When participants sent an e-mail signalling their willingness to participate they were randomized to either the experimental or control conditions and provided with the associated files required for participating in the study, as well as informed about the expected length of the procedure, in what way to report their results, and other details such as the ethical guidelines the study followed. The digital files provided to participants included: (1) an instruction document containing all the steps of the experiment adapted based on group with the difference that the control version did not mention mindfulness meditation, (2) a mindfulness meditation instruction document sent only to experiment-condition participants, and (3) the ANT file.

Data were collected from the 13th of March to the 7th of April. Participants were excluded from the study if they could not respond with their study results before the end of the experiment. However, there was an exception for one participant who requested to send in their results on the 8th of April. One further exclusion criterion was not being able to provide data corresponding to all parts of PANAS and ANT in this study: There was no exclusion for reporting of all data for one of either.

14 participants were recruited to the study. The retention rate of the study was 50%, as seven participants dropped out before reporting any results. Out of the remaining seven participants (1 without university education, 2 undergraduates, 4 graduates; 4 males, 3 females), one participant in
the experimental group did not report ANT results due to technical errors. Age of participants ranged from 24 to 52, with a mean age of 35. Three participants ($M_{age} = 42.00$, $SD_{age} = 15.62$) were assigned to the experimental group via randomization. Four participants ($M_{age} = 30.00$, $SD_{age} = 3.74$) were assigned to the control group by randomization.

**Procedure.** In the present study, I chose the experimental design of a randomized, posttest-only, control-group design (See Figure 1). Pre-tests were excluded to avoid sequence effects. All instructions were delivered in written form in English through Microsoft Word documents to minimize biases like different treatment by experimenters. A random number generator based on atmospheric noise was used to allocate participants to either the experimental or control-group conditions.

![Figure 1. Illustration of the randomized, posttest-only, control-group design used in this study.](image)

The settings of the experiment varied, with the participants using digital devices to access the instructions. However, the participants were instructed to implement the following conditions to their setting at the time that they partook in the study: (a) bright lighting; (b) performed in the afternoon (13-18:00 pm); (c) limitation of noise and distractions by being in a quiet room.

The ANT was administered through a digital tool provided by Fan (n.d.). Participants were instructed to download ANT (ver. 1.3.0). The ANT computer file was delivered via email and contained a Java version of the test (See the Assessment measures section for more details).

At the beginning of the procedure, each participant of the experimental condition read the instructions and engaged in mindfulness meditation alone for 15 minutes in a secluded room.
Participants were instructed to set a timer, such as one found in a mobile phone, to 15 minutes during meditation. Directly after meditation experimental-group participants filled in PANAS and performed the ANT. Participants of the control group performed the ANT and answered PANAS but did not participate in a meditation exercise.

After answering PANAS all participants were also instructed to answer questions regarding age, sex, education level (graduate, undergraduate, or no university education), and English proficiency (low, medium, or high) on a separate page. The levels of English proficiency were defined in the following manner, from low to high: (a) has trouble with most English reading or comprehension, (b) comprehends English in everyday speech and writing, and (c) rarely encounters trouble comprehending English. All participants were asked to estimate their total previous experience of meditation using the following five levels: (a) less than 10 hours, (b) less than 100 hours, (c) between 100 and 1.000 hours, (d) more than 1.000 hours, and (e) more than 10.000 hours. Those in the experimental condition were additionally asked to answer the question “After meditating I felt calmer” with a yes or a no.

Four control questions were used to gauge the extent to which participants followed the instructions and if there were any distractions during their participation in the study. The questions were: 'Did you follow the instructions?', 'Did you partake in the study in the afternoon?', 'Was there any part you did not understand?', and 'Were you at any time distracted during the study, and if so by what?'.

Meditation instructions were primarily based on the characteristics of mindfulness meditation described by Kabat-Zinn (1982), and by general meditation descriptions by Frisch (2006) regarding aspects such as the placement of the hands. Furthermore, the instructions were informed by relevant meditation descriptions from other researchers (e.g., Brewer et al., 2011; Nash & Newberg, 2013; Ospina et al., 2007; Phongsuphap, Pongsupap, Chandanamattha, & Lursinsap, 2009; Tang et al., 2015) to limit bias.

Summarized, the instructions of mindfulness meditation were as follows: (a) sit erect in a
chair with your shoulders back and your back straight; (b) look down or forward with your eyes open or closed; (c) try to sit as perfectly still as possible; (d) place your hands on your thighs; (e) concentrate on your breath, belly, bodily sensations, sounds or sights around you, or a mantra; (f) maintain steady attention and transition from a concentration on one object to a moment-to-moment attention to the changing field of events and experiences around you; (g) if your attention drifts repeat the two previous steps.

**Assessment measures.** This study measured alerting, orienting, and executive attention, negative affect, and positive affect. The measurement materials ANT and PANAS were used to measure these dependent variables. PANAS instructions were adjusted to ask participants to report their affect for the last hour if they were in the control condition, and for the duration of the meditation procedure if they were in the experimental condition. This PANAS change was conducted since the procedure was designed to investigate how mindfulness meditation affects mood shortly after practice, as asking about a person's experience of negative affect over longer time periods would then be less relevant.

**Positive and negative affect schedule (PANAS).** PANAS was created by Watson, Clark, and Tellegen (1988) for the sake of filling the gap of reliable and valid measures of affect. It is stated by Watson et al. (1988) that PANAS consists of two 10-item mood scales, one concerning positive affect and one negative affect (See Appendix for a full list of the items). Summated, positive affect regards the degree a person feels alert, active, and enthusiastic (Watson et al., 1988). Negative affect relates to subjective distress and an assortment of aversive mood states (Watson et al., 1988). PANAS is rated on a 5-point scale ranging from 1 (very slightly or not at all) to 5 (very much; Watson et al., 1988). The test-retest reliability of PANAS extends from .39 to .71 depending on time frame, and is generally above .50 (Watson et al., 1988). PANAS is internally consistent, and has good convergent and discriminant correlations (Watson et al., 1988). Other research has displayed Cronbach alphas of PANAS at or above .90 (Serafini, Malin-Mayor, Nich, Hunkele, & Carroll, 2016).
**Attention network test (ANT).** ANT was developed to provide a behavioral measure of the efficiency of the three attentional networks within a single task (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005). Alerting attention is defined as attaining and maintaining a state of high sensitivity to incoming stimuli, orienting attention is the selection of information from sensory input, and executive control is defined as relating to mechanisms that resolve conflict among feelings, thoughts, and responses (Fan et al., 2002; Fossella et al., 2002). The ANT is a combination of the Eriksen flanker task and a cued reaction time (RT) task (Fan et al., 2002). The Eriksen flanker task is represented in ANT by the six stimuli used.

In the ANT, participants are asked to indicate if a central arrow points left or right (Fan et al., 2002). Participants are instructed to fixate on a central cross that appears on a computer screen, and from this baseline other conditions are introduced. For instance, the arrow may appear above or below the fixation point. There are four cue conditions, where cues in the form of asterisks may appear before the arrow (1) in the centre, (2) above and below the fixation point at the same time, (3) above or below separately, or (4) not at all. The way the arrow is accompanied by flankers or not creates six different stimuli: (1) a lone left-pointing arrow, (2) a lone right-pointing arrow, (3) a left-pointing arrow with two left-pointing arrows on each side, (4) a right-pointing arrow with two right-pointing arrows on each side, (5), a left-pointing arrow with two right-pointing arrows on each side, and (6) a right-pointing arrow with two left-pointing arrows on each side (Fan et al., 2002).

A session of ANT consists in three experimental blocks (Fan et al., 2002). Each block contains 96 trials (4 cue conditions * 2 target locations * 2 target directions * 3 flanker conditions * 2 repetitions) and every trial has five events. The events are the following: (a) a fixation period lasting 400-1600 ms at random, (b) a cue condition for 100 ms, (c) another fixation point for 400 ms, (d) simultaneous presentation of flanker conditions and the target until participant response or up to 1700 ms if no response, and (e) a post-target fixation period with a duration calculated based on RT (3500 ms – duration of first fixation period and participant RT). Each trial lasts for 4000 ms and an experimental block lasts for roughly five minutes (Fan et al., 2002). Participants can take a
pause between blocks.

The results of the three networks are calculated by subtracting the RT measured for competing cues (Fan et al., 2005). For the alerting network, the RT of the center-cue condition is subtracted from the no-cue condition RT. The orienting network score is calculated by subtracting the spatial RT score from the center-cue RT score. Lastly, the executive network is measured by subtracting the congruent RT score from the incongruent RT score (Fan et al., 2005). Fan et al. (2002) have shown that RT and error rate are increased in incongruent compared to neutral and congruent conditions.

The alerting network of the ANT has a test-retest correlation of .52, whereas the orienting and executive control networks have correlations of .61 and .77 respectively (Fan et al., 2002). Employing the Spearman-Brown prophesy formula, MacLeod et al. (2010) calculated test-retest RT correlations of the executive network at .81, the orienting network at .55, and the alerting network at .38. In one study measuring brain network efficiency, the inferior parietal gyrus and thalamus were strongly linked with the alerting network of ANT, the inferior occipital gyrus and paracentral lobule with the orienting network, and the thalamus, parahippocampal gyrus, and dorsolateral superior frontal gyrus with the executive network (Xiao et al., 2016). Van Veen and Carter (2002) proposed that the ACC is involved with conflict monitoring and has connections to systems related to top-down control, which may be interpreted as stating that the ACC enables executive attention (Hölzel et al., 2011).

**Results**

The hypotheses of this study was that mindfulness meditation would on average decrease negative affect and improve attention when compared to the control condition. Data were distributed normally (p>.05) for all variables except ANT accuracy, as assumed by Shapiro-Wilk tests and seen through Q-Q plots. Therefore, to test the hypotheses negative affect and attention means were compared between the two groups via t-tests (excluding ANT accuracy). Aside from attention data of accuracy, only correct responses were included in the calculation of attention
Four independent samples t-tests (one for negative affect and three for the three types of attention measured) were used to analyze the four main dependent variables. Levene's test for equality of variances was conducted for each t-test to assess whether variance was about equal between the groups or not. SPSS (ver. 25) was employed for the t-tests and Levene's tests. See Table 1 for an overview of results between experimental and control groups.

Table 1. *PANAS and ANT Means (SD) Compared Between Meditators and Non-Meditators*

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>n</th>
<th>Experimental Mean (SD)</th>
<th>Control Mean (SD)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative affect</td>
<td>7</td>
<td>16.33 (3.79)</td>
<td>16.50 (7.05)</td>
<td>.97</td>
</tr>
<tr>
<td>Positive affect</td>
<td>7</td>
<td>37.00 (2.00)</td>
<td>29.50 (6.56)</td>
<td>.12</td>
</tr>
<tr>
<td>Alerting attention</td>
<td>6</td>
<td>72.50 (3.54)</td>
<td>49.50 (16.92)</td>
<td>.07</td>
</tr>
<tr>
<td>Orienting attention</td>
<td>6</td>
<td>51.00 (1.41)</td>
<td>49.25 (8.10)</td>
<td>.70</td>
</tr>
<tr>
<td>Executive attention</td>
<td>6</td>
<td>49.00 (2.83)</td>
<td>100.75 (20.32)</td>
<td>.03</td>
</tr>
<tr>
<td>Reaction time</td>
<td>6</td>
<td>558.00 (42.43)</td>
<td>600.75 (59.20)</td>
<td>.42</td>
</tr>
<tr>
<td>Accuracy</td>
<td>6</td>
<td>97.50 (.71)</td>
<td>98.00 (2.00)</td>
<td>.33</td>
</tr>
</tbody>
</table>

*Note. SD = Standard deviation. PANAS = Positive and Negative Affect Schedule (Watson, Clark, & Tellegen, 1988). ANT = Attention Network Test (Fan, McCandliss, Sommer, Raz, & Posner, 2002). All results were analyzed via SPSS (ver. 25).*

There was no significant statistical difference between participants who meditated and those who did not in terms of their reported experience of negative affect; t(5) = -.04, p = .97, 95% CI [-11.02, 10.70]. Levene's test indicated that an assumption of homogeneity of variance was violated. Cohen's d and Hedge's g were .03.

There was no significant statistical difference between participants who meditated and those who did not in terms of their alerting attention; t(4) = 2.61, p = .07, 95% CI [-3.05, 49.05]. Variance was unequal between groups. Cohen's d was 1.88 and Hedge's g was 1.56.

There was no significant statistical difference between participants who meditated and participants who did not concerning orienting attention; t(4) = .42, p = .70, 95% CI [-10.79, 14.29]. Variance was not equal between groups. Cohen's d was .30 and Hedge's g was .25.
There was a significant statistical difference between meditators and non-meditators regarding their executive attention; \( t(4) = -3.39, p = .03, 95\% \text{ CI } [-94.20, -9.30] \). Variance was equal between groups. Cohen's \( d \) was 3.57 and Hedge's \( g \) was 2.93.

For exploratory purposes, I compared the results of the control questions used in this study and the answers to the two questions about meditation experience. All participants answered that they followed the instructions and performed the study in the afternoon (yes = 7, no = 0). No participant answered that they did not understand a part of the study or that they were distracted during the study (yes = 0, no = 7). All participants that meditated answered that they felt calmer afterwards (yes = 3, no = 0). One participant estimated that they had less than 10 hours of total meditation experience, three less than 100 hours, two between 100 and 1,000 hours, one more than 1,000 hours, and no more than 10,000 hours.

Further, additional independent samples t-tests were conducted post-hoc to compare positive affect and RT scores between experimental and control groups (See Table 1), PANAS and ANT scores between gender groups, and age between experimental and control groups and gender groups. Since ANT accuracy was not normally distributed, a two-independent-samples Mann-Whitney U test was conducted to investigate the distribution of accuracy across experimental and control groups.

There was no significant statistical difference between participants who meditated and those who did not in terms of their experience of positive affect; \( t(5) = 1.88, p = .12, 95\% \text{ CI } [-2.78, 17.78] \). Variance was equal between groups. Cohen's \( d \) was 1.55 and Hedge's \( g \) was 1.43.

There was no significant statistical difference between participants who meditated and those who did not with respect to their mean RT; \( t(4) = -.89, p = .42, 95\% \text{ CI } [-176.16, 90.66] \). Variance was equal between groups. Cohen's \( d \) was .83 and Hedge's \( g \) was .77.

Comparing ANT accuracy between the experiment (\( n = 2 \)) and control (\( n = 4 \)) groups, no significant difference was uncovered; \( U = 2.00, p = .33 \).

Comparing mean age between the experiment (\( M = 42.00, SD = 15.62 \)) and control (\( M = 41.67, SD = 16.52 \)) groups, no significant difference was revealed; \( t(5) = 1.48, p = .19, 95\% \text{ CI } [-7.88, 24.95] \). Variance was equal between groups. Cohen's \( d \) was .83 and Hedge's \( g \) was .77.
30.00, SD = 3.74) groups, no significant difference was uncovered; t(5) = 1.30, p = .31, 95% CI [-24.75, 48.75]. Homogeneity of variance did not exist between groups. Cohen's d was 1.06 and Hedge's g was 1.17.

Lastly, there was no significant difference between men and women on any variable except negative affect, where men (M = 13.00, SD = 4.08) had a lower mean than women (M = 21.00, SD = 3.00) which was statistically significant; t(5) = -2.84, p = .04, 95% CI [-15.24, -.76]. Variance was equal between groups. Cohen's d was 2.23 and Hedge's g was 2.30.

Discussion

A purpose of this paper was to overview the mindfulness and meditation literature and to clarify the effects of these practices on the brain. However, the scope of this overview was limited to a few specific (e.g., mindfulness meditation, OM meditation) rather than numerous meditation practices (though other practices were referred to in a few of the studies). Lastly, the main purpose was to conduct an empirical study rooted in this overview.

From the literature search, it was discovered that much research has displayed alterations in similar brain areas related to mindfulness and meditation. ER may be affected by both mindfulness and meditation, as evidenced by alterations in PFC areas, such as the DLPFC and MPFC, and subcortical regions such as the ACC and amygdala (e.g., Fox et al., 2014; Höölzel et al., 2007; Kang et al., 2012; McConnell & Froeliger, 2015; Tang et al., 2015; Wheeler et al., 2017).

Meditation and mindfulness appear to affect attention, as interpreted based on associations with attentional networks, the DMN, and areas such as the orbitofrontal cortex, IC, and ACC (e.g., Allen et al., 2012; Brewer et al., 2011; Fox et al., 2016; Garrison et al., 2015; Jha et al., 2007; Vago & Silbersweig, 2012).

Various other regulatory, inhibitory, or executive functions are related to mindfulness and meditation and connected brain changes in the corpus callosum, IC, ACC, and frontoparietal control system, among other regions (e.g., Fox et al., 2016; Luders et al., 2012; Sperduti et al., 2012; Vago & Silbersweig, 2012).
The hypotheses of the experiment, that mindfulness meditation would on average decrease negative affect and improve alerting, orienting, and executive attention, were largely not supported. Four t-tests were conducted to analyse the data with respect to the original hypotheses, and additional t-tests were conducted post-hoc to investigate other variables of interest.

Concerning the four initial t-tests, only the test for executive attention displayed significant results (although alerting attention neared significance). Meditators were on average twice as fast as non-meditators in the congruent to non-congruent attention comparison. Studies have demonstrated support for the improvement of executive attention through mindfulness meditation (e.g., van den Hurk et al., 2010), and since the executive network is usually displayed as having the largest test-retest correlations out of the three networks (e.g., Fan et al., 2002) this can help explain why the executive but not alerting or orienting networks had significant results.

When comparing mean values between the experimental and control groups the results appeared to support the hypotheses about as much as they did not. For example, participants who meditated reported experiencing less negative affect and more positive affect than participants of the control group. But at the same time, participants of the control group sometimes performed better on aspects of the ANT, as evidenced by lower scores (i.e., for alerting and orienting attention). Nonetheless, most t-test results were not statistically significant, likely influenced by the small sample size.

Out of the 14 participants that applied to the study, only six completed all parts of the experiment and one all parts except the attention measurement. Such a low sample size may influence the likelihood to discover significant results despite mostly high effect sizes. For instance, Cohen (1994) gives the example that to detect a medium difference (d = .5) between two independent samples 64 participants are required in each group. Thus, it is to no surprise that few significant results were discovered in this study even if prior research has indicated that mindfulness meditation supports mechanisms such as emotion and attention regulation which in turn may affect the prevalence of negative feelings and the performance on attention tasks.
Since there were only two participants in the experimental group when comparing the attention measurements (as one experimental-group participant did not leave attention data), it is dubious whether such a small sample size can be said to constitute a group at all. For instance, perhaps it would be more accurate to consider the experiment a case study due to the low amount of participants? These considerations emphasize the importance of sample size and the limited conclusions that can be drawn from the current study.

As for the meditation experience and control questions, it appears participants understood the instructions and did not experience difficulties with the procedure itself (aside from the previously mentioned technical issue for one participant). Further, although the sample size is small, the three meditators all answered that the mindfulness meditation made them feel calmer. Thus, while there were no pre-tests, the manipulation check might indicate that negative affect did not increase because of the experiment. Lastly, the distribution of estimated previous meditation experience was spread out similarly between the two groups and appears to not have confounded the results.

The independent variable of this study was mindfulness meditation. The meditation procedure included (a) assuming a comfortable position, (b) focusing attention on an object (e.g., the breath, a mantra, a sound, a sight), (c) maintaining said attention steadily without distraction, and (d) transitioning from concentration to an open monitoring of the whole of moment-to-moment experience. This variable was designed to test the short-term induction effects of mindfulness meditation, and thus this study is limited to conclusions regarding such effects. For instance, although all meditators reported feeling calmer after the meditation one can not assume that this effect lasted long after the meditation.

Several studies (e.g., Leite et al., 2010; Young et al., 2009) have conducted meditation or mindfulness experiments favorably while relying on participants understanding and using written instructions to engage in the described practices, as well as in locations other than a laboratory or similarly controlled setting. Sliwinski, Katsikitis, and Jones (2015) have illustrated the potential role
of digital tools in promoting mindfulness-related training. Lastly, Querstret, Cropley, and Fife-Schaw (2017) used an online course to administer mindfulness. Thus, there is some evidence that studies can use written instructions and digital tools to perform meditation or mindfulness experiments and successfully induce the desired meditation or mindfulness effects.

Periods of meditation or mindfulness interventions of less than half an hour at a time have been linked to improved attention, SR, mood, and cough reflex sensitivity (Arch & Craske, 2006; Broderick, 2005; Gorman & Green, 2016; Tang et al., 2007; Young et al., 2009). One study compared the effects of listening to audio-books and engaging in mindfulness meditation for 20 minutes once a day over four days (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). Mindfulness meditation, but not audio-books, reduced anxiety and fatigue, and improved working memory and executive functioning (Zeidan et al., 2010). With that in mind, it appears there is some support for the use of shorter periods of meditation or mindfulness-induction techniques.

Finally, among the post-hoc tests investigating positive affect, accuracy, and mean RT between experimental and control groups, and all PANAS and ANT variables between men and women, only the t-test comparing men and women on negative affect displayed significant results. Several studies (e.g., Fujita, Diener, & Sandvik, 1991; Verhofstadt, Buysse, De Clercq, & Goodwin, 2005) support a notion of gender differences in the prevalence of negative affect (i.e., that women score higher on negative affect on average), but other studies (e.g., McRae, Ochsner, Mauss, Gabrieli, & Gross, 2008) appear to disconfirm such findings.

From another viewpoint, since most of the t-tests did not discover any significant differences between men and women this might imply these groups have more similarities than differences. Furthermore, there were non-significant (p = .31) mean age differences between the experimental and control groups, although effect sizes (Cohen's d = 1.06, Hedge's g = 1.17) were large. Similarly, significant age differences were not found (p = .98) between males and females (Cohen's d = .02, Hedge's g = .02). Thus, age does not appear to have been an impactful factor in this study.

Limitations and Future Directions
The paper was narrowed in its breadth to mainly deliberate on definitions and theories of mindfulness, certain meditation practices (e.g., FA meditation, mindfulness meditation), and their connections to the brain and aspects such as affect, executive attention, SR, and ER. Ergo, the preponderance of research in these topics was excluded through the aim of the paper. In addition, many articles (e.g., Chiesa & Serretti, 2010; Leyland, Rowse, & Emerson, 2019; Opialla et al., 2016) could not be detailed in this paper due to the total amount of allowed words.

As the experiment did not include a pre-test to inspect if groups were roughly equal at the beginning, and between-subjects designs rely on chance by randomization to equate groups, it is possible that the compared groups were not equal pre-intervention. This could increase the error variance and skew the results, and is a limitation in this study. With the small sample size this issue could be exacerbated as outliers would more greatly affect the mean. For instance, Borg and Westerlund (2012) describe that with smaller sample sizes the risk of type-II errors increases alongside the standard error of the mean.

Due to convenience sampling, the sample mainly consisted in undergraduate and graduate students from the University of Skövde. As such, results collected in this study may be biased by the nature of the sample. For example, Lauricella (2014) writes that undergraduate students comprise a group of which it is of particular importance to manage stress and where meditation may play a distinctive role. Thus, it may be premature to assume that the results of this study generalize to other samples.

In this study, all instructions regarding how to participate and perform the tasks of the study were delivered via electronic devices and computer files. Although not all individuals are equally proficient in using such tools, this variable was expected to be controlled by the use of randomization. However, by choosing this less controlled method of delivering information to participants a systematic effect may yet have biased the results. For instance, Lauricella (2014) discovered that, when comparing in-person to digital meditation instructions, 59% of participants preferred the former over the latter. Reasons for this preference included less distraction and greater
personal connection (Lauricella, 2014). Therefore, the choice of instruction delivery in the present study may have tilted the results for both groups in an unintended manner. This was not expected to affect statistical significance as both groups were affected similarly due to randomization, but may reduce the generalizability of the findings and decrease the appeal of the study to potential participants.

One participant reported that ANT (ver. 1.3.0) would not function when inputting the word guest as the group name. This was solved by using the alternate testant as group name along with its password, as enabled by the work of Fan (n.d.). Previous participants had no issue using the guest group name, but when testing I encountered this issue myself at the time that the one participant reported it. When I opened the program by using testant and then re-opened it by inputting guest, the issue did not re-appear. If other participants who exited the study encountered this issue without reporting it, which may have been the cause of their exiting the study, this may be a limiting factor of this study in that it may have decreased the sample size and thus lowered power.

The study was administered to participants via e-mail using digital tools such as Word document files. On the one hand, the experiment could not be tightly controlled in terms of the behaviors of the participants and settings of the experiment. On the other hand, participants were requested to follow specific instructions and implement their participation within certain parameters, such as the time of day being between 13-18:00 pm. Regulating the time during which participants are allowed to partake in the experiment may be important as time of day has been linked with aspects such as hypothalamic-pituitary-adrenal axis activity (e.g., Kudielka, Schommer, Hellhammer, & Kirschbaum, 2004).

The experiment was controlled by the instructions used, but how participants followed these instructions was not verified objectively. However, four control questions were used to assess the extent to which participants followed the instructions. Answers to these control questions indicate that participants did not experience confusion or difficulty during the experiment.

In future studies probabilistic sampling, larger sample sizes, and experimental designs less
prone to technical malfunctions may increase power and decrease the risk of type-II errors, and subsequently improve chances of discovering fruitful results of mindfulness meditation.

Furthermore, there remain many topics, theoretical connections, and experimental designs to be explored in the mindfulness and meditation literature not covered by this paper (e.g., exploring decentering, reperceiving, and related constructs and their neural correlates to clarify possible differences, ego-depletion effects or possible counteraction of mindfulness, or further differentiating between mindfulness meditation and methods such as OM).

**Conclusion**

The aims of this paper were to present an overview of mindfulness and of specific meditation practices, provide links to their effects on the brain, and to conduct an experiment grounded in the overview.

In the study, there were no significant statistical differences between the mindfulness meditation group and control group for any variable except executive attention. The result for executive attention is in line with previous studies on mindfulness meditation and attention.

There are several limiting factors to this study, including a small sample size, a restricted control of the experimental setting and participant behavior, and possible technical difficulties with the ANT. Therefore, what conclusions may be drawn from the data of this study is limited. Nonetheless, participants reported feeling calmer after meditating, understanding the instructions, and not being distracted while participating. Effect sizes were generally large, implying there were differences between the groups on some of the variables that were not trivial.

Can mindfulness meditation alleviate aspects of ill-being and improve attention? Based on the literature overview of this paper and functions such as attention-regulation and ER, it appears there is support for such a notion. However, such ideas received little support in the study of this paper, possibly influenced by the low sample size.
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Appendix

Positive and Negative Affect Schedule (PANAS)

This scale consists of a number of words that describe different feelings and emotions. Read each item and then list the number from the scale below next to each word. Indicate to what extent you have felt this way over the past week.

1 = Very Slightly or Not At All
2 = A Little
3 = Moderately
4 = Quite a Bit
5 = Extremely

____ 1. Interested  ____ 11. Irritable
____ 2. Distressed  ____ 12. Alert
____ 3. Excited  ____ 13. Ashamed
____ 5. Strong  ____ 15. Nervous
____ 7. Scared  ____ 17. Attentive
____ 8. Hostile  ____ 18. Jittery
____ 9. Enthusiastic  ____ 19. Active

Note. Items 1, 3, 5, 9, 10, 12, 14, 16, 17, and 19 comprise the positive-affect score. Scores can range from 10 – 50, with higher scores representing higher levels of positive affect. Items 2, 4, 6, 7, 8, 11, 13, 15, 18, and 20 represent negative-affect. Scores can range from 10 – 50, with lower scores representing lower levels of negative affect.
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