The Neural Effects Of Mindfulness Interventions On Depression: A Systematic Review

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Abstract

Depression has increased among adolescents and adults over the last decade. Effective treatments and techniques to improve personal well being and disorders like depression are much needed. Mindfulness is a psychological technique that involves actively paying attention to one's awareness of the present moment with nonjudgmental acceptance (Kabat-Zinn, 1990). While the effectiveness of mindfulness interventions has been widely studied, relatively little research has been done on the effects of mindfulness interventions on depression using neuroimaging techniques such as functional magnetic resonance imaging (fMRI) or electroencephalography (EEG). This systematic review includes four studies that investigates the effectiveness of mindfulness interventions on depression measured by fMRI or EEG and different rating scales measuring depression. The results from this systematic review shows that mindfulness interventions may have an effect on depression. Two of the studies (Ferri et al., (2017); Yang et al., (2016), found significant differences in the rating scales for depression. The studies also suggest that mindfulness interventions can impact the brain regions involved in negative emotional processing in individuals with depression, such as the default mode network (DMN) and the dorsal anterior cingulate cortex (dACC).

*Keywords*: mindfulness-interventions, depression, functional magnetic resonance imaging, electroencephalography
The Neural Effects of Mindfulness-interventions on Depression

The World Health Organization (2023) estimates that over 300 million people worldwide suffer from depression, which is the leading cause of disability worldwide. Depressive disorders have also increased over the last decade (Stringaris, 2017).

The word Depression is derived from the late Latin word Depressare and the classical Latin word Deprimere. “Depress” literally means to press down; “De” means “down” and “press” means “to press”. Depression appears to refer to a feeling of heaviness, of feeling “pressed down,” also referred to as “sad,” “blue,” or simply “down.” (Kanter et al., 2008). Depression also refers to the state of being pressed down or depressed. As early as 1665, depression was merely an indication of a low mood or spirit (Kanter et al., 2008).

Briefly, depression occurs in many ways. The definition of depression is not precise, or technical, nor does it have any essential components. Various symptoms, such as feeling sad or down, are associated with the condition (Kanter et al., 2008). Historical and environmental factors cause symptomatic variability and heterogeneity. However, some processes may be more common in depression, and understanding these processes would help limit what would otherwise be an assessment of many potentially irrelevant variables (Hayes et al., 1996). Lewinsohn (1974) pointed out two broad processes here: (a) losses, reductions, or persistent insufficiencies in positive reinforcement, and (b) increases in environmental aversive control (negatively reinforcing and punishing constraints). An estimated 3.8% of the population experience depression, including 5% of adults (World Health Organization, 2023). Suicide is the fourth leading cause of death in 15-29-year-olds, and more than 700,000 people die due to suicide every year (World Health Organization, 2023). There is a 30 times higher risk of suicide among adolescents who suffer from major depression disorder (MDD), compared to adults (Stringaris, 2017).

Research on mindfulness has experienced an exceptional growth in its research during the past 10 years. The National Health Service (NHS) has mandated mindfulness-
based cognitive therapy for certain patients suffering from MDD in the UK (Williams & Kabat-Zinn, 2011). Mindfulness interventions involve engaging in activities that focus on awareness of the present moment and non-judgmental acceptance of one's feelings, thoughts, and physical sensations (Baer, 2003). Research has shown that mindfulness interventions may have a positive affect on people's moods and overall well-being (Baer, 2003). Functional magnetic resonance imaging (fMRI) data suggest that mindfulness meditation training results in increased activations in brain regions associated with cognitive control, understanding emotions, and empathy (Vago & Silbersweig, 2012). Through these processes, mindfulness interventions may reduce anxiety and rumination, two common symptoms of depression (Vago & Silbersweig, 2012).

**Depression**

Depression is classified in the same manner as it is categorised in the International Classification of Diseases and Related Health Problems (ICD-10) (ICD-10 Version: 2019, n.d.). The Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) describes clinical conditions and diagnostic guidelines for mental health diagnoses (Paykel, 2008). Psychological and biological causes are acknowledged in the DSM-IV as well as several clinical characteristics of the disorder. According to DSM-IV, depressed mood and loss of interest or pleasure are two core symptoms of depression. In ICD-10, a further eligible symptom is decreased energy or fatigability, but since two of these symptoms must be present, depressed mood or loss of interest/pleasure also need to be present (Paykel, 2008). According to this view, depressive disorder is primarily a mood or affect disorder. Additional symptoms that contribute to the diagnosis of depression include appetite or weight loss, insomnia or hypersomnia, agitation or retardation, loss of energy or fatigue (DSM-IV), loss of confidence or self-esteem (ICD-10), guilt or worthlessness, reduced concentration or indecisiveness, and thoughts of suicide or suicide attempts (Paykel, 2008). In DSM-IV, eight symptoms are listed as qualifying for major depression, and at least five are required, including at least one of two core symptoms, as well as a duration of 2 weeks or longer.
(Paykel, 2008). A clinically significant amount of distress or impairment in function is present without a mixed episode, direct effects of drug abuse, medication or other substance (Paykel, 2008). Women are more likely to have depression than men, and people who have experienced abuse or severe losses are more at risk (Paykel, 2008).

A classic study was that of Aaron Beck which examined how frequently symptoms are present in people diagnosed with depression (Paykel, 2008). He and his colleagues tabulated a large sample of psychiatric patients at an early stage of the work ultimately leading to cognitive therapy and more immediately to his well-known Beck Depression Inventory (Beck et al., 1996). By dividing depressive symptoms into emotional, cognitive, motivational, physical, and vegetative symptoms, they showed that all symptoms increased with the severity of depression, except delusions (Paykel, 2008).

Activation and functional connectivity in the central cognitive network (CCN) are decreased in depression, while the default mode network (DMN) activation and functional connectivity are increased (Bursky et al., 2022). Based on functional brain imaging studies, the DMN appears to be involved in ruminative processes (Zhou et al., 2020). Depression strongly and consistently correlates with rumination (Zhou et al., 2020). Additionally, research clearly identifies a particular ruminative cognitive style associated with depression. Ruminative cognitive styles predict the onset, length, and severity of depressive episodes. Individuals with depression may spend a considerable amount of time “lost in thought,” reflecting on the day’s events and stewing over problems. This leads to negative thinking, poor problem solving, inhibition of operant behaviour, impaired concentration, increased stress, and increased problems (Kanter et al., 2008). Depression often results in dysregulation of the DMN. This neuronal network is also involved in automatic self-referential processing and internal mentation (Bursky et al., 2022). Among these processes are the retrieval of autobiographical memories and mental simulations of possible future events (Bursky et al., 2022). In the DMN, multiple interacting subsystems are involved in self-referential processing, each of which contributes to a different aspect of it. By providing
self-relevant memories to the medial temporal lobe subsystem, mental simulation of various events is facilitated. This process is facilitated by the medial prefrontal cortex (mPFC) subsystem, which uses these memories and their associations to create self-relevant mental simulations. The posterior cingulate cortex (PCC), which connects to the limbic system, integrates these two subnetworks (Bursky et al., 2022). Suppressed regulatory influence of prefrontal cortex (PFC) regions facilitates the recall of negative emotional events (Yang et al., 2016).

According to the study by Disner et al. (2011), biased thinking and rumination are associated with hyperactivity of a functional network including the amygdala, hippocampus, sub-genital cingulate, mPFC, as well as altered rostral anterior cingulate cortex (ACC) activity. Abnormal ACC activity suggests that suppressing negative thoughts may be harder for patients suffering from depression. Biased processing of emotional stimuli was associated with greater and longer-lasting amygdala reactivity, with hyperactivity of the left dorsolateral prefrontal cortex (DLPFC) and of the right DLPFC (Disner et al., 2011). Depressed patients also experience reduced positive affect and reward responses correlated with reduced activity in the nucleus accumbens and prefrontal cortex (Disner et al., 2011).

**Mindfulness**

The practice of mindfulness involves being aware of one's physical and mental states without judgement (Kabat-Zinn, 1990). Mindfulness meditation originated with the Buddhist Vipassana meditation techniques practised by Gautama the Buddha himself over 2500 years ago (Khoury et al., 2013). Since the mid-twentieth century, mindfulness has been incorporated into psychological interventions to reduce psychological distress and improve emotional wellbeing in clinical and non-clinical populations (Khoury et al., 2013). The use of mindfulness has now become a major part of several empirically supported psychological interventions like mindfulness-based stress reduction (MBSR; Kabat-Zinn, 1990), and mindfulness-based cognitive therapy (MBCT; Segal et al., 2001). Mindfulness interventions have been found to be effective in treating a variety of psychological disorders, including
anxiety and depression (Khoury et al., 2013). Scientists are only now beginning to understand the neurologic changes associated with mindfulness meditation's behavioural outcomes, although formal research on these outcomes dates back to the 1950s (Wheeler et al., 2017). In previous reviews, mindfulness interventions were found to affect physiological health positively (Keng et al., 2011) and cognitive ability (Chiesa et al., 2013). Taken together, mindfulness has been suggested to improve well-being, emotional reactivity, psychological symptoms, such as anxiety and depression, as well as cognitive abilities, such as selective and sustained attention (Wheeler et al., 2017). The practice of mindfulness meditation trains skills such as adaptive attention regulation and present-moment embodied awareness, which is particularly beneficial during depressive mental states characterised by negative ruminative thoughts (Van Der Velden et al., 2022).

Mindfulness practices should be considered in mainstream scientific discourse and are included in the American Psychiatric Association’s Practice Guideline for Major Depressive Disorder (Marchand, 2012). MBCT and MBSR are two of the most widely studied mindfulness-focused interventions, and they incorporate several components, including body scans, sitting meditation, and hatha yoga (Kabat-Zinn, 1990; Segal et al., 2001).

MBCT was developed by Zindel Segal, Mark Williams, and John Teasdale and combines cognitive therapy with mindfulness techniques (Teasdale et al., 1995) and is recommended as a treatment for unipolar depression. MBCT positively affects depression, anxiety, and psychological distress. The goal of MBCT is to alleviate psychiatric and physical symptoms (Marchand, 2012). MBCT have been studied for their effects on pain management and relapse prevention in depression (Marchand, 2012).

In 1979, Jon Kabat-Zinn developed MBSR to treat stress and pain in medical patients (Kabat-Zinn, 1990). A course in MBSR takes around 8-10 weeks to complete (Bishop, 2002). MBSR is beneficial for stress management and psychological health in both healthy individuals and those with medical or psychiatric illnesses (Marchand, 2012). MBSR involves several forms of mindfulness meditation, body scan and yoga all of which aim to
help participants change their automatic reactions to stressful situations into conscious ones. MBSR is based on sitting meditation, where participants sit on a chair or cross their legs on the floor and when they become distracted by their thoughts or feelings, they are instructed to focus on their breathing (Chiesa et al., 2013). As part of MBSR, individuals learn to become impartial witnesses to their own experiences, accept things exactly as they are in the moment, and not censor their thoughts. During the body scan, attention is moved from one body region to another (Marchand, 2012). Stretches, postures, and breathing exercises used in hatha yoga are included to relax and strengthen the musculoskeletal system (Marchand, 2012).

Brain imaging studies of meditation can be separated into those that examine (1) neurofunctional correlates, (2) neurofunctional changes after meditation training, and (3) structural brain changes among expert meditators (Boccia et al., 2015). During meditation, the brain activates areas associated with attention, mind wandering, episodic memory retrieval, and emotional processing (Boccia et al., 2015). Brain regions involved in the components of mindfulness meditation are regions involved in attention control (the anterior cingulate cortex and the striatum), emotion regulation (multiple prefrontal regions, limbic regions, amygdala and the striatum), and self-awareness (the insula, medial prefrontal cortex and posterior cingulate cortex and precuneus) (Tang et al., 2015). The ACC is the attentional region where changes in activity in response to mindfulness meditation are most consistently reported (Tang et al., 2015). Mindfulness meditation has shown positive effects on depression and can work as a therapeutic intervention (Gundel et al., 2018).

Mindfulness Interventions and Depression

A mindfulness meditation training program was originally introduced to treat depression as a way to prevent relapse for highly vulnerable patients (Winnebeck et al., 2017). According to a recent meta-analysis, preventative effects increase with residual symptoms (Winnebeck et al., 2017) so for patients suffering from depression, MBCT can be helpful (Winnebeck et al., 2017). Of particular interest is the change in the DMN activation to
investigate the effects of mindfulness training on the neuronal level and its suggested potential antidepressant effect (Bursky et al., 2022). Meditation has been found to have an impact on the CCN and DMN through increased activity in the DLPFC. It has been shown, for example, by Brewer et al. (2011), that experienced meditators exhibit decreased DMN activity (e.g., lower activation in the medial PFC and PCC) and increased functional connectivity between cognitive control and self-monitoring regions (such as an increase in the PCC’s, dorsal anterior cingulate’s, and DLPFC’s) while engaged in various forms of meditation (Bursky et al., 2022).

Studies have found that mindfulness interventions can reduce activity in the amygdala, a brain region associated with fear and anxiety, and increase activity in PFC, a brain region involved in self-awareness and emotion regulation (Chiesa et al., 2013). In the study by Ferri et al. (2017) patients suffering from treatment-resistant depression (TRD) also had reduced amygdala activity, which is related to more severe depression. Although the exact mechanisms through which mindfulness interventions may influence depression are not yet fully understood, research indicates that such interventions may modulate the activity of these brain regions associated with depression, such as the PFC and the amygdala (Brewer et al., 2011). Moreover, meditation has been associated with increased grey matter volume in the prefrontal cortex and increased functional connectivity between the prefrontal cortex and the amygdala (Tang et al., 2015). Such findings suggest that mindfulness interventions may influence depression symptoms through changes in the function and structure of relevant brain regions (Tang et al., 2015). The effects of meditation on brain structure and function have been studied using different neuroimaging techniques, and findings have helped clarify the biological underpinnings of meditation’s positive effects and its potential integration with standard therapy (Boccia et al., 2015).

**Measurement Methods Used in the Study of Mindfulness’ Effect on Depression**

With the help of various brain scanning techniques, it has been possible to measure what happens in the brain during depression and during mindfulness meditation. Studies
that have used EEG and fMRI have shown the effects that meditation has on brain structure and function, and the number of published studies is increasing (Boccia et al., 2015). Questionnaires have also been used to investigate the participants’ subjective experience.

**Functional Magnetic Resonance Imaging (fMRI)**

It is called functional magnetic resonance imaging (fMRI) when MRI is used to detect changes in blood flow associated with changes in neuronal activity in the brain. The imaging of haemoglobin is based on its magnetic properties (Gazzaniga et al., 2009). When oxygen is absorbed by haemoglobin in the bloodstream, it becomes deoxygenated (Gazzaniga et al., 2009). An fMRI detector measures the ratio of oxygenated to deoxygenated haemoglobin. This ratio is referred to as the blood oxygenation level-dependent (BOLD) effect. A rise in oxygenated/deoxygenated haemoglobin ratio is generally reported in fMRI results. When a brain area becomes more active, more blood is directed to that area (Gazzaniga et al., 2009).

**Electroencephalography (EEG)**

Electroencephalography (EEG) provides information about large-scale neural synchronisation by analysing spatial and temporal aspects of underlying brain activity (Lomas et al., 2015). EEG is a technique that measures the electrical activity of the brain. Surface recordings are made with electrodes placed on the scalp during EEG. Endogenous changes in electrical activity (as a result of changes in arousal) and changes triggered by specific events (stimuli or movements) are included in EEG signals (Gazzaniga et al., 2009). An event-related potential (ERP) is a change in electrical activity that occurs in response to specific events, such as the presentation of a stimulus. As events are repeated many times, averaging EEG signals reveals relatively little changes in neural activity. By removing background fluctuations from the EEG signal, the event-related signal is revealed with great temporal resolution (Gazzaniga et al., 2009). An error-related negativity (ERN) is an electrical signal derived from an EEG recording following an erroneous response. ERNs are seen as prominent negative deflections in ERPs, and they are hypothesised to originate in anterior cingulate cortex (Gazzaniga et al., 2009).
Rating Scales for Depression

There exist different rating scales for measuring depression. The Hamilton Rating Scale for Depression (HAM-D; Hamilton, 1960) measures variables on a five-point or a three-point scale. The latter is used when quantification is difficult or impossible. The variables are graded as absent, mild, clearly present, moderate and severe. The higher the score is, the more severe the depression is. The target group is adults and the scale is used to rate the severity of their depression by describing their feelings of guilt, mood, risk of suicide, sleep problems, anxiety, weight loss, and psychological symptoms (Hamilton, 1960).

Beck’s depression inventory (BDI; Beck et al., 1996) consists of 21 questions presenting four different statements and asking respondents to choose the option that best describes their feelings. Responses indicate varying degrees of depression (from "I don’t feel sad" to "I’m so sad I can’t stand it"), and this determines the scoring process, which assigns higher scores to responses indicating greater depression severity. The target group of the BDI is adults and young people with mental disabilities. The purpose of BDI is to measure the degree of depression in psychiatric patients (13–80 years) and the possible occurrence of depression in a normal population (Beck et al., 1996).

Center for Epidemiologic Studies Depression (CES-D; Radloff, 1977) consists of a list of ways in which the individual describes their feelings and behaviour. The person is asked to check how often she/he has felt this way during the past week related to a hypothetical situation. In such a question, the person is asked how often she/he experienced different emotions during the past week: rarely (less than one day), occasionally (1-2 days), frequently (3-4 days), or most or all of the time). A score is calculated based on the answers to the 20 questions. The possible range is 0-60. A score of 16 or higher is considered depressed (Radloff, 1977).

The Montgomery-Åsberg Depression Rating Scale (MADRS; Montgomery & Åsberg, 1979), was developed in 1979 by British and Swedish researchers as a supplement to the
other rating scale HAM-D. MADRS is more sensitive to changes caused by antidepressants and other types of treatment. The questionnaire asks about ten different symptoms including apparent or deported sadness, inner tension, sleep problems, loss of appetite, difficulty concentrating, weakness, dumbness, and pessimistic or suicidal thoughts. The scoring of the scale ranges from 0 to 6, and the overall score ranges from 0 to 60. The score that ranges from 0 to 6 describes a normal mood (not depressed), 7 to 19 describes mild depression, 20 to 34 describes moderate depression and the score of 35 to 60 indicates a more severe depression. The scale consists of nine questions (Montgomery & Åsberg, 1979).

Aim

The aim is to examine what is known about the effect of mindfulness on depression. Methods used in the studies are methods to image the brain and record brain activity as well as questionnaires. The field of neuroscience is well-suited to providing additional insight into the impacts of mindfulness interventions on depression, offering an invaluable perspective on the biological mechanisms underpinning such effects.

Methods

Search Strategy

This systematic review was conducted by way of search of the literature published between the year 2013 and 2023. The search terms used were Depression AND mindfulness AND (neuroimaging OR EEG OR fMRI). The electronic databases MedLine EBSCO and Web of science were used. Adaptations were made to the search strings to suit the format of each database. The duplicates were removed by automatic tools, the articles were screened, and records that didn’t relate to the research area were excluded. Titles and abstracts were then screened and assessed for eligibility. The focus of this study is on studies that aimed to investigate the effect of mindfulness on depression and that used the methods fMRI and EEG. Articles that are peer reviewed were used in the final selection of the studies and only original articles published in well-respected journals.
Inclusion and Exclusion Criteria

The inclusion criteria for the studies included were set as follows: 1) Adults, 18 years or older 2) studies measuring and reporting mindfulness interventions effects on depression
3) studies using fMRI, MRI, EEG or other neuroimaging techniques. All articles were required to provide original research and be in English. Papers that did not meet the inclusion criteria mentioned above were excluded from the review. One of the articles was removed from the systematic review because of the wrong age. The other four articles were excluded because MRIs and EEGs were not used to measure mindfulness's effects on depression (see Figure 1 for a PRISMA flow diagram).

**Data Extraction**

The following were extracted: Reference, Subjects, brain imaging and depression measure, intervention and duration, and the results. See Table 1 in the results section showing the data.

**Results**

The four studies' sample size ranged from 13 to 117 participants. In all four studies the participants were over 18 years old. Three out of four studies (Ferri et al., 2017; Williams et al., 2020; Yang et al., 2016) had the same time duration of 8 weeks during the mindfulness intervention and the fourth (Fissler et al., 2017) did not specify the time duration. Three out of four studies (Ferri et al., 2017; Williams et al., 2020; Yang et al., 2016) used fMRI/MRI, and one (Fissler et al., 2017) used EEG. See Table 1 for a summary of the reviewed studies, demographics and methodology. The results from this systematic review shows that mindfulness interventions may be effective against depression, as seen by reducing scores in all of the rating scales (BDI-II, MADRS, CES-D, & HAM-D). Two of the studies (Ferri et al., 2017; Yang et al., 2016), found significant differences in the rating scales for depression. The studies also suggest that mindfulness interventions can impact the brain regions involved in negative emotional processing in individuals with depression, such as within the DMN and dACC.
Study Designs

I will briefly describe the design of each article that I have selected in my systematic review and then discuss their results.

Table 1

Summary of the reviewed studies; Demographics and Methodology

<table>
<thead>
<tr>
<th>Reference</th>
<th>Subjects</th>
<th>Brain Imaging and Depression Measure</th>
<th>Intervention and duration</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferri et al (2017)</td>
<td>Participants with treatment-resistant depression (N=84)</td>
<td>fMRI</td>
<td>8 weeks of MBCT or health enhancement program (HEP) with a 52 week follow-up.</td>
<td>fMRI results found a significant relationship between mean amygdala activation and HAM-D percent change scores at the 52-week follow-up assessment, indicating that the greater the mean amygdala activation at baseline, the greater the improvement in depression severity at the 52-week follow-up (b = .19; t (44) = 2.57, p = .0136). The results from the HAM-D showed a percent reduction in depression severity for each group at each time point. The results showed that baseline amygdala activation was a unique predictor of depression severity, with a negative correlation, (b = -0.39; t(69) = -2.76, p = .007).</td>
</tr>
<tr>
<td>Fissler et al. (2017)</td>
<td>Depressed participants (N=74)</td>
<td>EEG</td>
<td>MBCT and control training, 25 min twice a day, six out of seven days during each week using recorded guided meditators. provides a reduced (ERN) relative to healthy controls, in the absence of task conditions that induce increased salience of errors and threat.</td>
<td>All ps &gt; .10 for the EEG and BDI-II results, indicating that the differences found were not statistically significant.</td>
</tr>
<tr>
<td>Williams et al. (2020)</td>
<td>Previously depressed participants (N=23)</td>
<td>fMRI</td>
<td>MBCT, 8 weeks</td>
<td>The result found reduced activation in the dACC/medial superior frontal area (related to self-blame) after MBCT, indicating a change in processing self-blaming feelings at the neural level. MADRS show 4.2 (3.5) at baseline and post-MBCT 2.2 (3.4). No significant change was found.</td>
</tr>
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</table>
Yang et al., (2016) Depressed Individuals (N=13) No control group. Mean age 24.53(+5.89)

fMRI CES-D MBSR, 8 weeks

The study identifies differences in brain activation patterns as measured by fMRI. The study found that short-term mindfulness meditation training yielded lowered activation in the DMN and decreased association with the salience network (SN) while increasing association with the central executive network (CEN).

The participants showed a significant reduction in depression scores after meditation training, as measured by the CES-D scale, with the mean score decreasing from 16.23 ±9.54 to 9 ± 6.20.

Previously Depressed Patients

The study by Williams et al. (2020) aimed to investigate the neural correlates of MBCT in individuals previously diagnosed with MDD related to self-blaming emotions. The study used fMRI to better understand the neural mechanisms underlying emotions, such as self-criticism and self-reassurance, that are linked to depression. Participants completed the self-report measure MADRS. MADRS depression symptoms show 4.2 (3.5) at baseline and post-MBCT 2.2 (3.4) (See Table 1). No significant change was found. The internal consistency of MADRS in the sample was α=0.61 at baseline and α=0.71 at post-MBCT. The study identified the dACC as the area activated during tasks involving the rehearsal of personalised guilt experiences compared with neutral, non-guilt conditions, as well as in other negative psychological concepts, including social rejection, embarrassment, and negative evaluation feedback. The study found a reduction in activation in the bilateral dorsal anterior cingulate/medial superior frontal gyrus after MBCT compared to baseline. Further, exploratory analyses showed that increases in self-kindness after MBCT correlated with reduced activation in the PCC/precuneus in self-blame versus rest contrasts (Williams et al., 2020).
Neural Changes Seen in Individuals with TRD vs Healthy Controls

Ferri et al. (2017) investigated the differences in emotion regulation between individuals with TRD and healthy controls. The study conducted fMRI to observe the amygdala reactivity of individuals with TRD during emotional stimuli processing before and after receiving MBCT or a health enhancement program (HEP). HAM-D was used to qualify the criteria for depression. The study compared the effectiveness of MBCT and HEP for TRD patients, finding that MBCT produced greater short-term improvements in depression than HEP. Neuroimaging acquisition methods and image processing details suggest that the TRD group showed greater amygdala activation in response to negative emotions than the control group. The study found that relative to the healthy control group, the TRD patients demonstrated less amygdala activation during affect labelling, and marginally less during gender labelling. Furthermore, although MBCT produced greater short-term improvements in depression than did HEP, overall baseline amygdala reactivity was predictive of long-term clinical outcomes in both groups (Ferri et al., 2017). The results from the HAM-D showed a percent reduction in depression severity for each group at each time point. The results showed that baseline amygdala activation was a unique predictor of depression severity, with a negative correlation (b = -0.39; t(69) = -2.76, p = .007). However, there was no significant difference in treatment response between MBCT and HEP groups at Weeks 24, 36, and 52 according to the independent t tests (p > .05).

Neural Changes in Chronically Depressed Individuals Performing Mindfulness Training

Fissler et al. (2017) investigates the effects of mindfulness training on the neural correlates of error processing in chronically depressed individuals. Six days a week, the mindfulness training involved 25-minute meditation sessions twice a day. In this practice, mindfulness practices are used to increase attentional control, body awareness, insight, and emotional regulation, following the standard sequence of mindfulness based interventions. In order to assess the severity of depressive symptoms, the BDI-II was used. The neuroimaging
method EEG was used. EEG data indicated that, compared to the depressed group, healthy controls had higher error-related negativity (ERN) and a difference between error-response magnitudes and correct response negativity (ΔERN). The chronically depressed patients showed significantly blunted expression of the ERN in frontocentral and frontal regions compared to healthy controls. Following two weeks of training, the chronically depressed patients in the mindfulness condition (n=24) showed a significantly increased ERN magnitude in the frontal region, but there were no significant changes in patients who were in the resting control condition (n=22). The EEG analysis results revealed significant differences between the two groups, as the depressed group exhibited a higher number of error trials when compared to the healthy control group (Fissler et al., 2017). The BDI-II results showed a decrease in depression symptoms in both the mindfulness and resting control groups. Before the intervention, the scores for both groups were high (Mindfulness: 26.1, Resting Control: 28.2), indicating severe depression. After the intervention, the scores for the mindfulness group decreased to 10.0 and the scores for the resting control group decreased to 19.4. However the results showed a ps > .10 for the EEG and BDI-II results, indicating that the differences found were not statistically significant.

**Neuronal Changes of Mindfulness Meditation in Depressed Participants**

Yang et al. (2016) aimed to investigate the benefits of mindfulness meditation training on depression, as well as its impact on the DMN in the brain. The mindfulness meditation training program in this study was designed based on self-observation training and consisted of eight 1.5-hour sessions over a period of eight weeks. The program was based on MBSR, and participants were instructed to perform meditation exercises during the first hour of each session. The program included simple physical and breathing exercises to help the participants focus their attention on their thoughts. Participants were required to practise daily sessions at home lasting around 45 minutes. All participants were screened for psychiatric or neurological conditions before enrolling in the program and had no previous meditation experience. In this study, fMRI was used to investigate the impact of short-term
mindfulness meditation on the brain. Resting state fMRI (rs-fMRI) has also been used to explore differences between experienced meditators and novices. The study aimed to compare resting state activation to meditation state activation.

The results showed differences in functional connectivity both between states (rest versus meditation) and between time points (before versus after training). The study suggests that the neuronal effects observed after 40 days of meditation, which was shown to affect depression-related psychometry, also reduced connectivity in the DMN, which is hyper-connected in MDD. Within-network consistencies were strongly affected in the DMN, in a direct comparison of meditation state and resting state. The neuroimaging results of the study showed that the work effects in part coincided with changed local fluctuations and reduced connectivity between the insula and dACC (Yang et al., 2016). The result from the CES-D before the intervention was a mean score of 16.23 ±9.54, which slightly surpassed the cutoff score for depression. However, after meditation training, the mean CES-D score was reduced significantly to 9 ± 6.20, indicating a significant reduction of depression scores. Finally, the correlation between changes in the CES-D scores and changes in connectivity of the components was not significant for dACC.
Discussion

This systematic review aimed to examine what is known about the effect of mindfulness on depression. Overall, the studies indicate some evidence for the neuroplastic effects of mindfulness interventions on brain networks, functional connectivity, and emotional processing associated with depression. By targeting these neural mechanisms, mindfulness interventions hold promise as adjunctive treatments for depression and may provide insights into the underlying neuronal mechanisms of their antidepressant effects.

The four studies included in this review (Ferri et al., 2017; Fissler et al., 2017; Williams et al., 2020; and Yang et al. 2016) have some similarities and differences. All of the studies investigated the effects of mindfulness interventions on depression and used various methods such as EEG and fMRI and self-assessment scales to measure changes in depression-related psychometrics. All studies examined mindfulness intervention over an 8-week period, except Fissler et al., (2017) who does not mention a specific time duration of the mindfulness intervention program.

The study by Yang et al. (2016) focused on changes in functional connectivity in the brain, whereas the other studies did not specifically focus on this aspect. The Fissler et al. (2017) study used EEG analysis to compare the brain activity of depressed patients and healthy controls during error processing, whereas the other studies did not use this method. The interventions used in the studies were different. The Williams et al. (2020) study investigated the effects of MBCT on self-blaming emotions related to depression, while the other studies did not target this specific aspect. The Fissler et al. (2017) study compared mindfulness and resting control interventions, while the other studies did not use a resting control group.

There are similarities in activation within specific brain regions in the studies mentioned. Throughout the studies, there is a focus on exploring differences in brain activation before and after mindfulness interventions, specifically in individuals with
depression. The studies utilise different neuroimaging techniques such as EEG and fMRI to explore the effects of mindfulness interventions on brain activation patterns. Specifically, the studies by Yang et al. (2016) and Williams et al. (2020) both identified reduced activation within the dACC in response to negative emotions or during tasks involving the rehearsal of negative experiences. Both of the studies (Yang et al., 2016; Williams et al., 2020) also identified regions within the DMN that were affected by the different mindfulness interventions (MBCT or MBSR), especially posterior parts of the brain, which are relevant when thinking about oneself and retrieving autobiographical memories. The study by Ferri et al. (2017) identified differences in amygdala activation in response to emotional stimuli between individuals with treatment-resistant depression and healthy controls. To conclude, the studies suggest that mindfulness interventions can impact the brain regions involved in thinking about oneself, rumination and negative emotional processing in individuals with depression. These results are in line with previous research (Vago & Silbersweig, 2012), that also states that mindfulness interventions reduce rumination, a common symptom of depression.

The study by Yang et al., (2016) and Ferri et al., (2017) found a significant reduction in the rating scales of depression. The result from the study by Yang et al. (2016) shows that the CES-D before the intervention was a mean score of 16.23±9.54, which slightly surpassed the cutoff score for depression. However, after meditation training, the mean CES-D score was reduced significantly to 9 ± 6.20, indicating a significant reduction of depression scores. The study by Ferri et al. (2017) used the HAM-D to assess depression severity in patients with treatment-resistant depression. The results from the HAM-D showed a percent reduction in depression severity for each group at each time point, for example in the beginning of the treatment the score of the HAM-D in the MBCT group was (n = 33), and in the end of the treatment the score of the scale was (n = 24).

The results from the studies that used different measurement scales for depression (BDI-II, MADRS, HAM-D, and CES-D) provide information about the effectiveness of
mindfulness-based interventions in reducing symptoms of depression in different patient populations. Overall, the studies suggest that the different mindfulness interventions may be an effective intervention for reducing symptoms of depression, as demonstrated by improvements on all of the different scales in all of the studies (Ferri et al., 2017; Fissler et al., 2017; Williams et al., 2020; Yang et al., 2016), even if the results weren't significant in all of the studies. Additionally, the studies suggest that mindfulness interventions can have short- and long-term benefits for individuals with depression, as revealed by changes in symptoms both immediately following the interventions and over time. The studies provide evidence to support the use of mindfulness interventions as a treatment approach for individuals with depression. Mindfulness techniques can modulate neural mechanisms associated with depression and offer practical applications for enhancing emotional regulation, addressing maladaptive cognitive processes, and promoting self-compassion.

Limitations and Future Research

Despite their contributions, all reviewed studies have limitations. These include small sample sizes, potential selection biases, incomplete subject data, and the lack of control groups in some cases.

The limitations of the reviewed studies in the text are small sample sizes, potential selection biases, incomplete subject data, and the lack of control groups in some cases. Additionally, caution should be exercised when interpreting neuroimaging results due to possible false-positive rates and practice effects over time. The studies by Williams et al. (2020) and Yang et al. (2016) was both limited by the small sample size due to incomplete imaging artefacts. The study by Williams et al. (2020) was limited by the lack of a control group, while the study by Ferri et al. (2017) did not have a treatment-responsive group of depressed patients as a control group.

Regarding the limitations of this review, the search was limited to two databases, and it covers the years of 2013-2023. If more databases were used and older articles were taken
into account when researching this area, the scope of the articles would have been broader. It is possible that relevant studies were excluded since this review contains only four articles, which is a limitation to this systematic review. Two reviewers would have made this study’s results more reliable and the selection bias better. According to fMRI or EEG results, mindfulness intervention’s effects on depression are very limited, which limited the number of articles included in this review. This review also has limitations due to the different types of mindfulness interventions being studied and the different aspects of depression disorders.

Based on the information provided, some areas for future research could include further controlled studies to confirm the findings of the study on the potential therapeutic effects of mindfulness meditation training on depression. Specifically, future research could investigate the activation and changes in brain functioning in regions associated with attention, learning, and emotion processing, as well as changes in functional connectivity between brain areas. Future studies could also explore the effects of different types and lengths of mindfulness meditation training on depression and well-being. Further research is needed to establish long-term effectiveness, optimal time of the mindfulness intervention, and feasibility in diverse populations. Integrating mindfulness practices into treatment protocols and understanding their mechanisms of action requires further exploration.

Conclusion

Taken together the results from this review suggest that mindfulness interventions may have a positive effect on depression, as measured by neuroimaging methods and improvements on different measurement scales. The studies also suggest that mindfulness interventions can impact the brain regions involved in negative emotional processing in individuals with depression, such as the DMN and dACC.

The studies mentioned in this systematic review highlight the importance of investigating the neural correlates of mindfulness meditation and its potential therapeutic effects on depression. While further research is needed to fully understand the mechanisms
through which mindfulness interventions may influence depression, the findings of this review indicate that such interventions may be a useful tool in treating depression.
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