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Meditation and Yoga can Modulate Brain Mechanisms that affect Behavior and Anxiety-A Modern Scientific Perspective

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Abstract

Meditation and Yoga techniques are receiving increased attention throughout the world, due to the accumulation of evidence based research that proves the direct and indirect benefits of such practices. Based on studies conducted so far, it has been found that the practice of meditation triggers neurotransmitters that modulate psychological disorders such as anxiety. This paper will review the psychological effects of the practice of meditation, the role of neurotransmitters, and studies using EEG and fMRI.

Keywords

Meditation; Yoga; Neurotransmitters; brain mechanisms; Behaviour and Anxiety

Introduction

The art of meditation, which was once considered to be exclusively an Eastern practice, often associated with religion and spiritualism, has become a more scientific modality in recent years, and is accepted for routine practice in many parts of the world. No wonder Yoga Day is celebrated on 21st June all over the world. Due to the observed direct and indirect benefits of Yoga practices, controlled research has been carried out on the physiological and neuropsychological aspects of various meditation techniques. Studies comparing other forms of psychotherapy, along with meditation therapy have also become part of the global research agenda.

There are various forms of meditation that have been designed and established by several *sage-scientists* of India since the time of *Patanjali*, who is known as the Father of Yoga according to regional Indian sources. Though there are many types of meditation practices, some of the well-known practices in the West are “Mindful Meditation”, “Transcendental

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Meditation" and "Kundalini Meditation". More than 60% of the Indian population directly or indirectly, practice some kind of meditation as part of their traditional culture. In India, schools offer courses in Yoga and Meditation. For instance, the Vethathiri Maharishi Institute for Spiritual and Institutional Education (VISION) in India has created a complete curriculum for Yoga staring from kindergarten and going all the way to Ph.D level.

The Indian government has recently allocated a Ministry with a budget exclusively to fund research in Yoga and Ayurveda. Recently, the benefits of Yoga have been well-recognized in the west. Harvard, MIT and Yale universities have encouraged research on such a new modality. The NIH has allocated a budget for this research as part of the National Center for Complementary and Alternative Medicine (NCCAM). Many of these meditation techniques are used for different specific applications, and studies have shown that they have varying neurophysiological effects. The most common application of meditation is to alleviate stress and anxiety; therefore meditation is often considered as a form of relaxation therapy, more than as an alternative to traditional drug-based medicine.

Stress and Anxiety Disorders

Stress is a factor that has been shown to predispose chronic sufferers to develop many diseases including heart attack, cancer, infections and other neurological disorders. Meditation has proven to be a very good solution for stress management. Research conducted at the Maharishi Mahesh Yogi Institute for Management and Technology in the US has produced strong evidence of the direct benefits of meditation on stress management. Stress is also largely responsible for anxiety disorders. Anxiety disorders affect approximately 40 million adults in the United States, ages 18 and older, in a given year [1]. It is alarming that a large national survey found 8% of teens (13 to 18 years) have some form of anxiety disorder. There are several types of anxiety disorder. Apart from Generalized Anxiety Disorder (GAD), when one worries excessively, Obsessive-Compulsive Disorder (OCD) is another type of anxiety disorder in which affected individuals display uncontrollable, intrusive thoughts, obsessions and compulsions in an attempt to reduce the anxiety. Post-Traumatic Stress Disorder (PTSD) is when the victims who have been directly or indirectly affected by a traumatic event, suffer distress and either display avoidance symptoms, re-experiencing symptoms, or hyperarousal symptoms [2]. Social anxiety is not only the fear of having to be in front of people, but is also the fear of engaging in social activities because the sufferer is anxious of being judged [3]. And lastly, anxiety also stems from phobias—an intense fear of a certain specific stimulus.

This article will review the neurobiological changes produced by meditation, and its applicability to anxiety will be covered.

Neurotransmitters

Neurotransmitters play a key role in modulating and regulating behavior and anxiety. Studies have demonstrated a negative correlation between gamma-aminobutyric acid (GABA) activity and anxiety. Although GABA receptors can be found throughout the brain, research has indicated particularly decreased GABA activity in the hippocampus, lingual gyrus, middle temporal gyrus, visual cortex [4], orbital cortex and insula [5] in patients with

panic disorder when compared to controls. GABA knockout mice (or in other words, mice that have been engineered to have dysfunction of GABA receptors) exhibited fear related behaviors, such as heightened sensitivity to natural aversive stimuli, increased ability to recall negative associations and augmented harm avoidance behavior [6]. Moreover, a patient with severe GAD was found to have a genetic mutation in a GABA receptor subunit; this mutation lessened the binding capacity of substrate to the GABA receptors [7]. These studies prove that lower levels of GABA or GABA receptors are associated with higher levels of anxiety.

Positron emission tomography (PET) was used to compare the regional cerebral blood flow (rCBF) of eight Tibetan Buddhist meditators. As they performed complex cognitive tasks, it was found that the meditators had significantly higher rCBF in the prefrontal cortex (PFC) than the controls. The PFC is a brain region that is largely responsible for executive functions such as decision making and problem solving ability [8]. When the prefrontal cortex is stimulated, it activates the reticular nucleus of the thalamus (RE), which in turn produces GABA [9, 10]. Meditators also have a higher threshold concentration and alertness, which are cognitive functions controlled by the PFC. Therefore, an increase in the PFC region upon meditation is correlated to an increase in GABA production since the RE will be excited [11]. It has also been hypothesized that transcendental meditation increases GABA-inergic tone [12]. By increasing GABA levels, meditation may help to decrease anxiety levels.

Serotonin, a powerful neurotransmitter, plays a major role in mood regulation. A deficiency of serotonin is associated with depression, and a study revealed that serotonin knockout mice, with the deletion of a serotonin receptor, IA, exhibited more fear. Another experiment, which compared the serotonin levels of healthy controls with those of patients diagnosed with panic disorder using a PET scan, found out that the patients had about one-third lower level of serotonin 1A receptors in regions such as the anterior cingulate, posterior cingulate and midbrain raphe [13]. It is remarkable that several studies performed on participants after they concluded their meditation sessions, observed a rise in the breakdown products of serotonin in the urine [8, 14]. In one such study of Transcendental Meditation practitioners, the urine samples were analyzed for serotonin, and the meditators exhibited a higher level before meditation when compared to the controls, and a much higher level after meditation [15].

Norepinephrine (NE) is another neurotransmitter involved in anxiety. The brain region called locus coeruleus is hypothesized to contain the greatest concentration of NE in the brain, and an increase of activity in this region together with increased NE has been identified in individuals with anxiety. In an experiment, when NE release was decreased in rats, the rats were not able to respond normally to fear inducing stimuli [16]. These findings suggest that a lower level of NE indicates lesser anxiety, and this has been confirmed in meditators. In a study which compared NE levels between two groups of heart failure patients—one which practiced meditation and another which attended weekly meetings, it was determined that the group practicing meditation displayed lower levels of NE in their blood samples compared to the controls [17]. In another experiment, regular meditators utilizing either TM or Sidhi-TM techniques expressed lower NE levels than the control

group of healthy subjects, when their plasma catecholamine levels were measured in mornings and evenings [18].

A neurotransmitter that is commonly associated with reward-motivated behavior and social anxiety is dopamine. A research experiment found out that people with generalized social phobia tended to have lower dopamine levels than healthy subjects [19]. Another study that incorporated PET scans observed an increase in dopamine levels in the ventral striatum of participants during practice of Yoga Nidra meditation [8, 20]. There is also some evidence that when melatonin, a hormone generally known to aid sleep, was injected in rats, the rats showed less anxiety and spent longer time in a plus-maze [21]. Moreover, a review cited nine different studies that concluded that lower levels of anxiety could be produced when melatonin was given as a medication versus placebo [22]. In a within-subject study, plasma melatonin levels were obtained from a group of TM-Sidhi meditators when they meditated on two different nights—one night they meditated for about an hour, and another night, they sat quietly instead for the same one hour. The research study discovered that the melatonin levels, which were approximately the same pre-meditation, were higher in the nights they meditated than in the control nights [23].

Brain Electroencephalographic Measurements

Alpha waves are generally associated with more relaxed and alert states of mind, and an experiment conducted noticed that individuals clinically diagnosed to have anxiety disorder displayed lower activity of alpha waves, while individuals who were only prone to have anxiety had slightly higher alpha activity, and non-anxiety prone normal subjects exhibited the highest alpha activity; therefore, the number of oscillations in the alpha band increased as the levels of anxiety decreased [24]. Furthermore, a biofeedback study that enabled subjects to control their alpha activity found that when individuals with higher anxiety traits increased their alpha wave activity, they displayed a reduction of anxiety symptoms [25]. Research studies comparing alpha wave activity in meditators and control subjects concluded that people who meditate display higher alpha activity than the controls [26].

Theta oscillations assist with alertness and the ability to process information quickly [26]. Frontal midline theta waves which can be stimulated during mental tasks as well as in nocturnal sleep have also been found to play a key role in personality traits. A research study showed that higher theta wave activity was identified in individuals with the lowest anxiety scores, the highest extrovert scores and the lowest scores on a neurotic scale [26, 27]. Therefore, an increase in the theta levels can decrease anxiety levels. Research studies have also reported an increase in the theta activity in meditators, and four studies mentioned an increase in the frontal midline theta power during meditation [26]. Individuals who have practiced meditation for a much longer time displayed higher theta and alpha power than non-meditators [26, 28]. While studies have predominantly found an overall increase in alpha waves in meditation, a few reports have found a decrease in alpha power. Studies conducted on theta waves have more consistently displayed an increase in meditation.

Mindfulness and Mantra

Mindfulness meditation is the conscious direction of attention to an object, person, idea or stimulus; this activity requires plenty of attention. Studies have proven that attention training programs have helped to lower anxiety levels, as the subjects are able to shift their attention away from the threatening stimulus [29]. In a research experiment, victims, who were sexually abused in their childhood, partook in an 8-week mindful meditation course, and they displayed statistically significant decreases in their PTSD symptoms, anxiety and depression [30]. When a group of PTSD survivors went through eight sessions of psychoeducation (education about mental health), and another group underwent mindful meditation, it was reported the latter group expressed a higher reduction in PTSD symptoms at the end [29, 31]. The efficacy of this meditation technique was analyzed in another study that performed a three year follow-up after a previous study in which 22 individuals diagnosed with anxiety partook in an 8 week long mindfulness based meditation program [32, 33]. Eighteen of these subjects participated in the follow-up study, and the data obtained demonstrated that the clinically and statistically significant reductions of the anxiety levels were still observed at the follow-up.

Another study conducted on subjects using fMRI concluded that there was higher connectivity in the least anxious patients [34]. A research study carried out on 26 patients with GAD compared the effectiveness of Mindfulness Based Stress Reduction (MBSR) and Stress Management Education (SME) using fMRI. The study found from the Blood Oxygen Level Dependent (BOLD) responses that meditation practice (MSBR) resulted in more connectivity between the amygdala and several regions of the PFC, amygdala and dorsolateral PFC when compared to SME. This was also consistent with the measured Beck Anxiety Inventory scores, where the meditators showed lower mean scores for anxiety symptoms than the SME participants [35]. This comparison is illustrated in Figure 3:

Transcendental meditation (TM) using mantras is a technique where the participants silently repeat a word or phrase. Young adults in college were assigned to a TM program or wait-list control, and the TM group showed lower levels of anger, stress, depression and most importantly, anxiety after they were trained in TM [36]. additionally, two groups of war veterans with PTSD were studied; both received usual care, but one group went through mantra meditation. The meditators expressed higher reductions in PTSD symptoms and exhibited more improvement in their mental health, when compared to the control group [37].

When compared to a waiting-list control group and a group getting cognitive behavioral therapy (CBT), individuals performing Sahaja Yoga meditation proved to significantly reduce anxiety and depression [38]. Kundalini Yoga Meditation is the raising of body awareness by awakening the “chakras” or “kundalini energy” in the body, and there are several techniques; these techniques include meditation, breathing methods, yoga and mantras. An experiment conducted by Shannahoff-Khalsa et al revealed that a group of patients after 12 months of practicing Kundalini Yoga showed 55.6% improvement, and a reduction of 19.8 to 8.8 as a mean in the Yale-Brown Obsessive-Compulsive scale. In this

research study, the technique comprised a combination of yoga postures and breathing techniques [39].

Conclusions

Our brains do not contain fixed hardwiring; the neural pathways and circuits can in fact change with learning and with mental exercises, and meditation may be a harmless way to encourage the growth of new neurons (neurogenesis) along with the formation of new connections between existing neurons (synaptogenesis). By tying together the neurobiological effects of neurotransmitters, brain waves, mental exercise and the empirical evidence from the psychological experiments, it is evident that meditation is an effective treatment for anxiety, and it does not suffer from any side effects. It may also function as a preventive medicine; therefore, it is highly recommended to everyone and not limited to patients suffering from disease. This review has only highlighted observations from the several studies already conducted. However, it is imperative to conduct many more studies on a larger scale to substantiate the reported effects of the overall meditation approach, and by probing into the different effects of the various meditation techniques to see if differences in technique make a difference to the outcomes.

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Biographies

Divya Krishnakumar received her BS from UC San Diego in 2013, majoring in Cognitive Science and specializing in Neuroscience. With a fascination about the brain, she is particularly interested in researching about neurological disorders. Thus as an undergraduate student, she acquired research experience by working under the direction of distinguished neuroscientist Dr. V.S Ramachandran; she conducted research on individuals with OCD-like traits. Furthermore, she assisted with neurofeedback training on autistic children in Dr. Jaime Pineda's Cognitive Neuroscience laboratory. Her other passion is empowering young girls through a program called Full of Ourselves, which is a primary prevention program that emphasizes on increasing their overall mental and physical well-being.

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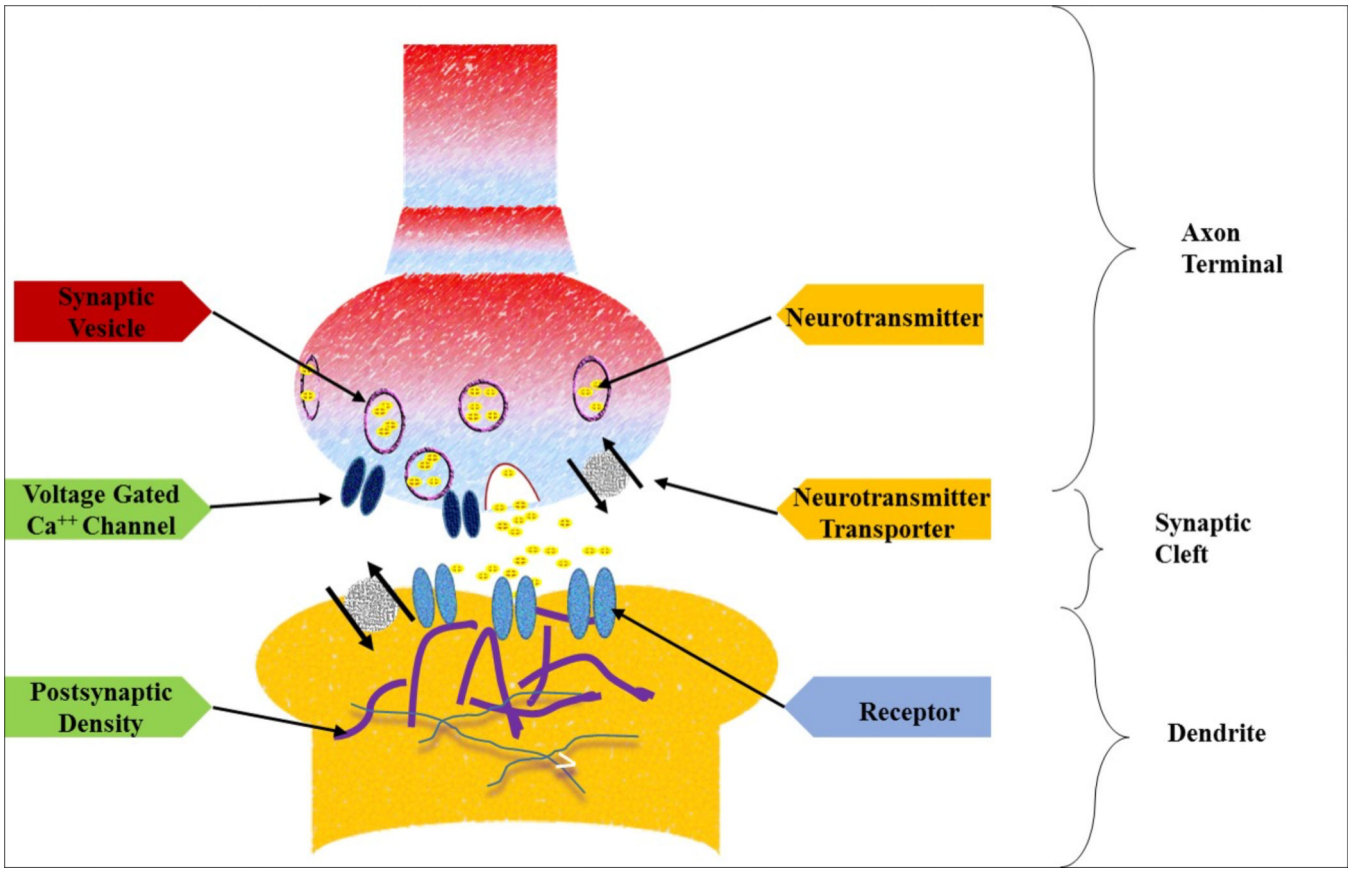

Figure 1.

Illustration of a Chemical Synapse. Neurotransmitters are essential brain chemicals that help relay information between neurons. At the synaptic cleft, the neurotransmitters are released from the axon terminal of one neuron. The released neurotransmitters then bind to the receptor sites of the postsynaptic neuron.

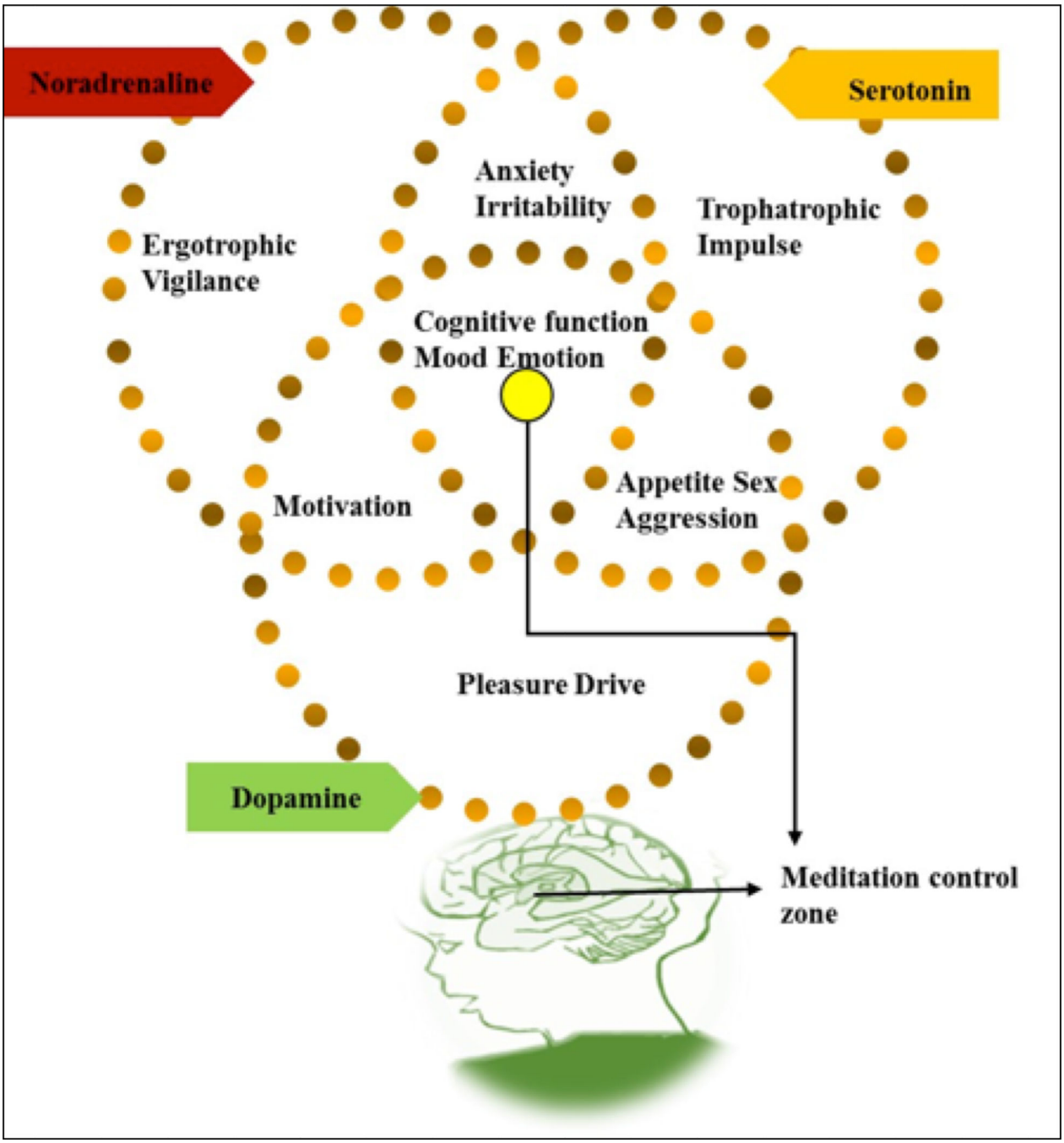

Figure 2.

The illustration provides a general view of the different roles of the common neurotransmitters—Noradrenaline (Norepinephrine), Dopamine and Serotonin. It is vital that the neurotransmitters are in balance for optimum common cognitive and physiological functionalities, and this can be achieved when the brain is in a meditative state.

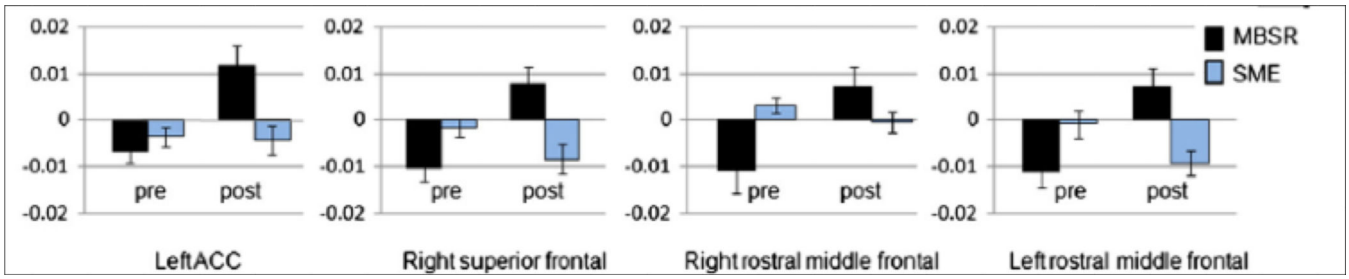

Figure 3.

A pre- and post- comparison of the functional connectivity of GAD patients between the individuals who underwent a Mindfulness Based Stress Reduction Program (MSBR) and those who participated in Stress Management Education (SME) [35].