

Review Article

Beneficial Effects of Yoga on Memory and Cognition Associated to Stress

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Abstract: Stress generally occurs due to the organism's non-specific response against some kind of demand imposed on them. The compensatory responses to these stresses are known as stress response. The stressful stimuli can advance the physiological and psychological effects on the body which includes executive functions of the brain. The prefrontal cortex shows an important connection between the circuits that are linked with emotions, memory and planning. Due to this activation of stressful condition or situation damage occurs in the prefrontal cortex because of the catecholaminergic nature of its innervating afferents in the other parts of the brain. Along with hippocampus, the amygdala and prefrontal cortex define the aspects of memory and visual processing within brain. The decrease in PNS and GABAergic activity that causes stress related disorders can be corrected by yoga practice resulting in amelioration of disease system in the brain such as reduction in anxiety and improvement in cognitive function. Depression, Post Traumatic Stress Disorder (PTSD) that are elevated by stress shows low heart rate variability (HRV) and GABAergic activity which can be improved in response to yoga based interventions. Yoga practices show increase in the proportion of gray matter and escalation in activation of amygdala and frontal cortex of the brain. It was concluded that breathing, meditation and posture based yoga increased overall brain function and activity.

Keywords: Yoga, Stress, Prefrontal Cortex, Cognition, Hippocampus, Amygdala

1. Introduction

Any change in the body's reaction due to its adjustment with the environment or surrounding and also due to one's own thought according to its needs caused by extrinsic or intrinsic stimulus is known as stress. The automatic response which we accomplish from these stresses is termed as stress responses [1]. Stress reaction can be of two types- negative and positive. Distress is a condition caused due to continuous stress effect which is an example of negative stress reaction [2]. Positive stress reaction can be helpful in improving achievement, motivation, adaptation etc. Even stress in its low levels can be useful, helpful and healthy [3]. Subjects who are exposed to stress are provoked for physical, mental, emotional, social, physiological, biochemical, cognitive diseases.

“According to American Psychiatric Association stress is described as a sense of being overwhelmed, worry, destruction, press, exhaustion and lethargy. Therefore, stress can influence people in every age, sex, race and situation and can result in both physical and physiological health” [4].

Stress can be classified into three different forms according to the:

- 1) Nature of stressor that consist of two classes i.e. Physiological stress and Psychological stress [5-6].
- 2) Stress influence on individual which comprises of two main branches i.e. Positive Eustress and Negative Distress [7-8].
- 3) Exposure to the duration of stressor which is bifurcated into Acute Stress (short term) and chronic stress (long term) [9].

Physiological stress symptoms include disrupted digestion including diarrhea, constipation and nausea, chest pain and rapid heartbeat, insomnia, low energy, headaches and twitching or shaking.

Psychological stress comprises of cognitive symptoms such as impaired concentration, trouble remembering homework, chronic worrying, reduced judgement, impaired speech and unwanted thoughts. It also includes depression and anxiety, anger, irritability or restlessness, making of bad decision. Psychological stress also comprises emotional symptoms such as impatience, feeling of sadness, restlessness, irritability and loss of interest.

Positive stress reaction can be helpful in improving achievement, motivation, adaptation etc. Distress is a condition caused due to continuous stress effect which is an example of negative stress reaction. Eustress further shows the following characteristics within an individual. It motivates & focus energy, feels excitement, improves performance, positive feeling of contentment etc.

Acute stress disorders may include flashbacks, nightmares or intrusive memories, avoidance of reminders of the event, difficulty remembering it, dissociation, an inability to experience positive emotions, anxiety, sleep disturbances, irritability and difficult concentrating.

Chronic stress disorders sign and symptoms can include: irritability, fatigue, headaches, difficulty sleeping and concentration, changes in appetite, rapid disorganized thoughts etc.

Now the different approaches to study stress includes three impactful approaches which include response based, stimulus based and cognitive transactional based process perspectives. Living begins ability to response stress according to the demands of the surrounding environment is generally response based perspective. This pattern of stress in case of both animals and humans shows a three stage pattern. This pattern is known is General Adaptation Syndrome (GAS). It shows alarm reaction i.e. fight and flight response, resistance stage i.e. bearing chronic stress and active use of body resources and last one is exhaustion stage i.e. damage of tissues and diseases tends to occur. Hans Selye is referred as the representative of this approach [10-11].

Secondly the stimulus based approach is determined from the studies of Holmes and Rahe [12]. It depends on the amount and severity of the stressors and evaluate their power to deplete individuals, it has been revealed that the average amount of needed effort to overcome some event might be a suitable index of its severity [13-14].

Cognitive transactional based process perspective tends to show a relationship between individual and surrounding environment. Here the individuals tend to show his/her demands from the surrounding environment and obtain all benefits and resources from it. Thus, it leads to destruction of the surrounding environment and threatening of their own life for future perspective [15].

Now, a complementary and alternative medicine therapy which is widely used to manage illness is yoga. In MBSR (Mindfulness Based Stress Reduction Program) yoga acts as

its main component which includes breathing techniques, physical postures and meditations. These results were used to get fruitful result in elimination of stress and its negative effects. To maintain a good coordination between mind and all aspects of body yoga plays a dominant role in this stressful condition. Therefore, there are several studies or experiments that shows the positive effects of yoga on stress causing disorders.

The present study aims at to determine the various aspects of stress on brain effecting memory and cognition with the positive effects of yoga on it.

2. Effects of Stress on Brain

Autonomic nervous system plays a pivotal role in the maintenance of stress for living beings to adapt within the surrounding environment, sympathetic nervous system activates or regulates many physiological functions within the body [16]. The intensively regulated pathway of stress response is done by hypothalamus as it secretes corticotrophin releasing hormone to stimulate pituitary gland which ejects adrenocorticotrophic hormone to blood stream which in turn maintains the intensively regulated stress response [17]. This in turn imparts the adrenal to release cortisol (glucocorticoid) and hence a negative feedback loop occurs on the Hypothalamus Pituitary adrenal axis (HPA). Corticotrophin hormone acts centrally to mediate fear related behaviors [18] and triggers other neurochemical responses to stress such as the noradrenergic system via the brain locus coeruleus [19].

2.1. Stress in Relation to Memory

The effect of stress causes the alteration within the hippocampus, which function as an important role in determination of memory. As a result, alteration in the hippocampus structure tends to be paired with deficits in the memory function [20-21]. It is caused due to a certain rise in the level of glucocorticoid and glutamate, with the depletion in the levels of brain derived nerve growth factor and inhibition of neurogenesis [22-25]. It has been seen through various studies that changes in hippocampus i.e. structural and functional changes do occur due to stress [26]. These structural changes include atrophy and neurogenesis disorders along with decreasing of dendritic branches due to increase in levels of plasma cortisol [27-28]. Analysis from hippocampus dependent loading data shows the negative effects of stress on learning. The subjects don't tend to be adapted to a new environment after being exposed to it [29]. An important process i.e. long term potentiation in memory formation is altered due to adrenal steroids [30]. Prefrontal Cortex (PFC) which regulates planning, attention, problem solving tends to be destructed primarily due to stress response. The hippocampus, pre frontal cortex and amygdala are important parts of brain that define the aspects of memory and visual processing in brain.

Traumatic stress leads to mental disorders i.e. POST TRAUMATIC STRESS DISORDER (PTSD). In this case the amygdala helps to show fear response [31-32] and due to

increase in stress response dendritic arborization occurs within it [33-34]. Lesions in the medial prefrontal dopaminergic system shows no ejection of peripheral cortisol due to stress along with failure to elevate sympathetic response to stress [35-36]. Thus, dysfunction of normal emotion and an inability to relate in social situation occur. Dendritic branching in prefrontal dopaminergic system reduces due to stress and also has inhibitory inputs.

2.2. Stress in Relation to Cognitive Impairment

The perception, interpretation and reception of perceived stimuli which helps in attention, learning, decision making is known to be cognition. Reduction in cognition takes place due to the effects of stress, which may increase again due to the changes in behavioral process leading to decrease in stress [37]. There is a complicated relationship impact of stress on memories which depends on the amount or duration of stress and the relevance of stressful event to be formed memories. The acute stress helps in the formation of those memories which doesn't involve working memories such as ongoing memories and procedural knowledge [38-39].

As it has been previously determined that glucocorticosteroids are released due to activation of stress, and now as it has lipophilic properties it can easily diffuse through the blood brain barrier and may show effects on processing and cognition [40]. Chronic stress can cause further severe complications such as pathophysiological changes occur within the brain and so causes changes in behavioral, cognitive, mood disorders [41].

In case of biochemical estimations, increase in the level of IL-6 and plasma cortisol occurs and decrease in the level of cyclic adenosine monophosphate (C-amp) responsive elements binding protein and brain derived neurotrophic factor is found [42]. This biochemical outcome is seen in people who tend to be affected with stress. Another important relationship between stress and mood based cognitive disorders is that both can be estimated from increased level of interleukins and TNF- α [43].

Further acute effects of stress are induced in a short term manner due to the beta adrenergic effects whereas chronic effects which occur for long terms due to changes in gene expression mediated by steroids i.e. adrenal steroids [44]. These steroids can lead to destruction of neurons. Hippocampus related cognition disorders like decrease in genesis of neurons in the dentate gyrus area of hippocampus region occurs due to stress action [45].

At the time of stress, the most vital region within the brain is hippocampus because cognitive processes like last memories can have severe effects on facilitation, inhibition and even generating distinct response to stress. Damage and atrophy occurs in the hippocampus due to stress [46]. As previously stated prefrontal cortex activities are destructed generally temporarily due to stress action. [47]. Locus coeruleus, is a key player for the production of norepinephrine neurotransmitter within pons. During fight or flight response, norepinephrine helps in messaging in SNS (Sympathetic Nervous System). The SNS provide neural extension to all parts of the brain and

spinal cord [48]. Within pons, raphe nucleus undergoes the transmission of serotonin neurotransmitter. When stress is combined with depression or anxiety then the mood is regulated by this neurotransmitter [49].

Alternative effects of stress on neural activity and spines within the amygdala and hippocampus have been frequently observed. It leads to cognitive changes. In the hippocampus region and BLA (Basolateral Amygdala) it has been noticed due to stress glutamergic signaling occurs. Due to this increase in amygdala activity which takes place in BLA [50], leads to expression of Brain-derived neurotrophic factor (BDNF) along with dendritic outgrowth and spine density increases [51] whereas in case of hippocampus BDNF expression decreases along with the hippocampal pyramidal cells receiving aversive sensory information from the entorhinal cortex are also inhibited due to cholinergic input mediated activation of CA1 dendrite targeting interneurons in fear of learning [52]. Stress causes the loss of spines and debranching of dendrites within the medial prefrontal cortex neurons. Chronic stress especially on the distal apical dendritic branches occurs due to the loss of axo-spinous synapses which tends to be over 30%. Treatment with corticosterone for 3 weeks has shown reversal of dendrites in the medial prefrontal cortex. Substance P, which is an 11 amino acid member of the tachykinin family binds to the receptor of neurokinin-1 during stress and thus produces anxiogenic effects [53-54].

Both, the memory formation and upgradation are damaged due to stress and thus it is the central action of stress on cognition. This is mainly in terms of contextual unrelated memories and complex decision making activities. Higher cognitive processes are likely to become impaired due to stress like goal directed behavior, self-control and working memory. Attention, attention shifting and top down control are some of the appropriate sequences of action for goal directed behavior. It is a process which upholds the important information in mind as in working memory. Stress impairs medial prefrontal cortex dependent cognition with the degree of impairment being correlated to the extent of dendritic shrinkage.

Peptide hormone named ghrelin which is produced by stomach is a stress mediator. After post translational acylation, ghrelin can pass through the blood brain barrier and binds to growth hormone secretagogue 1a in the BLA thereby enhancing fear learning, independent of HPA activation. Neurogenesis is enhanced by ghrelin whereas spatial learning and memory is impaired which is seen in adult mice. Early life stresses can lead to the development of IMD (Irritable bowel syndrome) within a person which is a chronic function disorder [55-57].

3. Ameliorative Effects of Yoga on Stress

3.1. Neurophysiological Effects of Yoga Breathing

Neurophysiological model to analyze the positive effects of yoga breathing was described by Brown and Gerbarg. In this model, Brown and Gerbarg showed or demonstrated that stretch receptors which are present in the alveoli as well as in

the baroreceptors, chemoreceptors and sensors tend to pass relevant information through vagal afferents and brainstem relay stations by the use of respiratory structures. The information which is carried by them is about the state, functioning and activity of respiratory system to the other Central Nervous System (CNS) structure. This leads to the influence of perception, cognition, emotion regulation, somatic expression and behavior. Therefore, this model determines the changes in rate, depth or pattern of breathing information collected through the signals of vagal afferents. These changes gain the highest priority and have rapid widespread effects on brain function [58-60]. Coherent breathing and resonant breathing using a fixed rate of three and a half of six breaths per minute, increases Peripheral Nervous System (PNS) and Heart Rate Variability (HRV) activity. A form of resistance breathing which is Ujjayi (ocean breadth) increases PNS activity. There has been evident research on the increase vagal tone and physiologic relaxation while chanting "OM" which involves slow breathing and airway resistance [61]. These techniques decrease abnormalities in the Autonomic Nervous System (ANS) providing mood improvement, decreased anxiety and improved health. This voluntarily controlled breathing patterns can affect the ANS.

The biological markers of stress are cortisol and brain GABA [62-63]. The level of these markers tend to alter accordingly due to stress i.e. depression and PTSD indicates increased HPA axis activity. This occurs due to increase amount of corticotrophin releasing factor and cortisol [64]. Decrease in the amount of GABA system also occurs due to these disorders. Increase in the amount of cortisol have been reported after interventions using yoga practices. Yoga practices reduces the stress induced allostatic load in GABAergic system and HPA axis [65]. Participants who are experienced in Transcendental Meditation (TM) for 3-5 years had significantly greater decrease in cortisol level than those with 3-4 months of TM experience [66]. From mild depressive symptoms to major depressive disorder, yoga based interventions are effective in treating them. This yoga based interventions includes Sudarshan Kriya Yoga, Iyengar Yoga and Resonance breathing.

The correction of abnormalities related to ANS and Gamma-Aminobutyric acid (GABA) also decreases PTSD symptoms. A network that tend to decrease symptoms by the yoga based practices comprises of interaction of the Prefrontal Cortex (PFC), hippocampus and amygdala which is associated with inputs from ANS and GABA system. Decrease in PFC activation and increase in amygdala activation occurs with failure of PFC to inhibit the amygdala has been seen in response to stressful tests [67]. In response to emotionally laden cues, PFC activity decreases in PTSD subjects, a group known to have reduced PNS activity, as opposed to the increased PFC activation seen in subjects with high PNS activity [68].

The PFC exerts tonic inhibitory control over the amygdala via GABAergic projections. PFC tends to become hypoactive due to conditions such as uncertainty and threat. As a result, over activity of amygdala doesn't occurs with emergence of

PTSD symptoms such as hypoarousal and re-expressing. This could represent a neural correlation of the failure of extinction of fear reaction over time as seen in PTSD [69]. PFC activation associated with increased PNS activity could improve inhibitory control over the amygdala via PFC GABA projections, decreasing amygdala over activity and reducing PTSD symptoms.

The Central Extended Amygdala (CEA) receives inhibitory GABAergic projections through the insular cortex. The GABAergic neurons from the CEA projects to the Parabrachial Nucleus (PBN) and Dorsal Vagal Complex [70]. In between the temporal and frontal lobes of sylvian fissure the insular cortex is located. The environment and interoceptive information in the form of sensory information are conveyed by the PNS via the Nucleus tractus solitaries (NTS) to the insular cortex, where according to Craig's neuroanatomical theory, a map of the internal state of the body is maintained [71]. For energy mobilization activation of amygdala is necessary, whereas over activation of the amygdala reflects allostatic load associated with the hypervigilant condition (excess arousal) in PTSD [72]. Restoration of strong tonic GABAergic inhibition of the amygdala would result in decreased output from the CEA to the hypothalamus and brainstem nuclei, reducing symptoms of hyperarousal, over reactivity, and re-experiencing in PTSD [73]. Psychological states such as anxiety, depression, and PTSD, associated with PFC hypoactivity and lack of inhibitory control, are characterized by poor habituation to novel neutral stimuli, pre-attentive bias for threat information, deficits in working memory and executive function, and poor affective information processing and regulation [74]. The presence of GABA neurons in the thalamus, insular cortex, amygdala, and hippocampus as well as GABA projections from both the insular cortex and the PFC to the amygdala completes the pathways that would constitute an anatomical substrate for the effects of ANS balance and imbalance on emotion regulation and cognitive function.

3.2. Structural & Behavioral Changes on Memory

Evidence of amygdala with decreased cerebral blood flow and frontal lobes with increased activation have been noticed in those subjects who practiced Iyengar yoga for a period of 12 weeks (60min daily) [75]. Research findings shows that after 1 training session of Hatha yoga in practitioners, there is a less activation of dorsolateral prefrontal cortex while viewing negative emotional images and distractors, greater stroop task response in the ventrolateral prefrontal cortex with yoga practitioners when presented with emotionally negative disorder images [76]. Also practitioners who received various yogasanas and pranayamas training for 1hr/day, 5days/week for 3 months showed an increase in hippocampal volume [77]. Greater amount of white matter connectivity within the insular cortex is seen in those practitioners for varying types of yoga indicates greater pain tolerance [78].

Uninostil and alternate nostril yoga breathing shows higher scores on a letter cancellation task after alternate and right nostril yoga breathing. It also shows increase in spatial

memory scores in left nostril breathing [79-80]. Increase in verbal task performance is seen in unilateral forced nostril breathing practitioners [81].

4. Conclusion

Stress can be of various forms depending on its nature, influence and duration. Most forms of stress are usually harmful for human beings as they lead to various forms of diseases. Yoga plays a pivotal role in the management of stress within the brain. Hypothalamus controls the entire pathway for stress response. Now, due to the effect of stress alteration do occur within the hippocampus which includes atrophy, neurogenesis and decrease in dendritic branches. Along with hippocampus, the amygdala and prefrontal cortex define the aspects of memory and visual processing within brain. Both of this are inversely proportional to each other with the exposure of stress. In the hippocampus region and BLA (Basolateral Amygdala) it has been noticed due to stress glutamergic signaling occurs. Due to this increase in amygdala activity which takes place in BLA, leads to expression of Brain-derived neurotrophic factor (BDNF) along with dendritic outgrowth and spine density increases whereas in case of hippocampus BDNF expression decreases along with the hippocampal pyramidal cells receiving aversive sensory information from the entorhinal cortex are also inhibited due to cholinergic input mediated activation of CA1 dendrite targeting interneurons in fear of learning.

This present review also highlights on the stressful condition in today's modern and advancing world and its management by practicing yoga. Yoga has a promising effect on brain complications related to memory and cognition. It comprises of the interaction of the prefrontal cortex, hippocampus and amygdala which is associated with the inputs from ANS and GABA system. Various forms of breathing practices increase PNS activity and improves deformities in the ANS. Yoga practices reduces the stress induced allostatic load in GABAergic system and HPA axis. Direct and indirect effects on the autonomic nervous system and GABA system can be understood through the ameliorative effects of yoga on stress. There are evidences, that increase in PNS and GABA activity is due to the interventions of Vagus Nerve Stimulation (VNS) and yoga. This may be effective in treatment resistant subjects who failed to respond to pharmacologic agents that increase activity in the GABA system. Further, it has also been seen from various studies that different forms of yoga practices could be helpful in the structural activation of brain along with its cognitive function that helps the individual in performing better task as well as increasing and improving their memory. Therefore, it can be concluded from the above study that yoga plays a pivotal role in the improvement of brain physiology affected due to stress interventions.

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Competing Interest

There is no competing interest to be declared.

Declarations of Interest

None.

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