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Neurobiological contributions to understand psychological trauma

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Abstract
Psychological trauma is one of the most prominent psychological problems every population confronts with. Understanding trauma is sometimes complex and comprehensive. Intrusive or painful experiences cause psychological trauma and it can influence the victim's psychological, behavioural and emotional states and ultimately it can make an impact at biological level too. Hence this paper tries to understand the psychological trauma with the help of neuroscience research evidences. The paper is divided into three major parts which include neuro-endocrinal, neuro-chemical and neuro-anatomical consequences of trauma. As the three systems are interrelated and inseparable in functioning this classification is made only for better understanding.

Keywords: Psychological trauma, neuro-endocrinological effects, neuro-chemical effects, neuro- anatomical effects

Introduction

The term 'trauma' stems from the Greek word meaning 'a piercing of the skin, a wound'. Freud (1920) used the word metaphorically to illustrate how the mind, being a protective shield as the skin to the body, could also be pierced and wounded by some negative experiences. Now a days many modern western societies are using the word trauma frequently to address a highly stressful situation or event which overwhelms a person's resiliency (Janoff-Bulman, 1992; McNally, 2005) [12, 14]. According to Shapiro (2002), trauma is "any event that has a lasting negative effect on the self or psyche" (p. 14). While the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR; American Psychiatric Association, 2000) [2] describes trauma in the diagnosis of posttraumatic stress disorder (PTSD) based on isolated, life threatening incidents.

Many people are exposed to traumatic experiences at some point of time in their lives, such as natural disasters, loss of loved ones, domestic violence, accidents, death, abuse or neglect. According to American Psychiatric Association, these events are characterized by being sudden or unexpected, by their shocking nature- including death or threat to life or bodily integrity- and by the subjective feeling of intense terror, horror, or helplessness (American Psychiatric Association, 2000; Cohen, Mannarino, & Deblinger, 2006) [2, 8]. Psychological trauma refers to the impact of an extreme stressor critical incident on an individual's psychological and biological functioning (American Psychiatric Association, 1994) [1].

Nature and symptoms of psychological trauma

As we discussed above, psychological trauma may arise when an individual is confronted with serious threat to one's physical or psychological integrity. American Psychiatric Association stated that this also may occur by witnessing these events happening to others. The intense fear caused by these events may be exhibited as disorganized or agitated behaviour in the individuals (American Psychiatric Association, 1994) [1]. The traumatized individuals are most likely to develop different types of psychological and behavioural symptoms that may include intrusive (persistent re-experiencing of the event through recollections in the form of images, thoughts, day dreams, and nightmares), arousal (hyper vigilance, irritability, difficulties with sleep, exaggerated startle response, difficulty concentrating, and angry outbursts) and avoidance symptoms (avoiding places and thoughts associated with the trauma, difficulty in recalling the event, numbing, loss of interest in other aspects of the life, withdrawal, derealisation, dissociation, restricted emotions).

Rationale of the study

Trauma is an experience, repeated trauma and chronic negative experiences affects the psychology of the victim and eventually it alters the biological conditions as well and can have an invasive effect (Bruice Perry, 1995). Based on these grounds, the rationale of the present study has been established. It is very important and essential to dig into the biological effects to understand effectively how traumatic experiences can dramatically affect and transform the individual's world into terror filled and confusing throughout the rest of his life. To explore this area we have to study the role of the brain, the part of the body which is central to process and internalize the traumatic experience. Brain is the part which mediates emotional, physiological, behavioural, cognitive and social function of the human being.

To explore the brain's role in understanding the psychological trauma, researcher has taken the help of the literature from the neurobiology, the branch of science that deals with the anatomy, physiology and pathology of the nervous system. To make it more clear and evident, researcher has divided the study into three major parts which includes neuro-endocrinological effects of trauma, neuro-chemical effects of trauma and neuro-anatomical effects of trauma. In this paper, besides these three major parts, it also been discussed the parallel psychological effects due to above mentioned neurobiological changes in the victim's body.

1. Neuro-endocrinological effects of psychological trauma

Cortisol and norepinephrine are the two endocrine secretions which are directly into blood flow and plays an important role

in regulating the stressful situations (Bremner, 2006). Whenever an individual confronted with a stressful event or traumatic experience, it immediately stimulates the amygdala in the brain which is the gateway to fear and emotion centre. Amygdala prepares sympathetic nervous system to make the body's emergency response system activated for fight or flight responses (Hass-Cohen *et al.,* 2014). The fight or flight hormone adrenaline is the key factor for this response that released from adrenal glands after receiving the signals from amygdala. Soon after adrenalin released, it transforms as epinephrine in the body. This neurotransmitter produces changes in human body which includes strengthened heart rate, heightened respiration, release of sugar into blood for greater energy and dilation of the pupils for improved vision, decreased blood flow into organs and increased blood flow into limbs. All these reactions make sure the individual to be ready enough to confront with the situation with a decreased amount of energy consuming and low blood loss.

This is the mechanism of the endocrine system for a single or short term traumatic event or experience. When it is the case of dealing with long term exposure to the stressful or threatening experiences, comparatively it takes much longer chain reactions and mechanism (Cohen-Hass *et al.,* 2014). The part of the brain to react first to a traumatic event is amygdala in both the cases of short term and long term exposure to trauma (Sapolsky, 2004) [20]. After being stimulated by the stressors, amygdala stimulates hypothalamus to secrete Corticotrophin Releasing Hormone (CRH). CRH stimulates the production and release of two hormones called adrenocorticotropic hormone (ACTH) and arginine vasopressin (AVP) from the anterior pituitary (Sherin *et al.*, 2011). These hormones in turn stimulate the release of glucocorticoids from the adrenal cortex. The occurrence of these hormones stimulates the adrenal gland to release cortisol into the bloodstream. The entire release of this sequence of hormones is coordinated by hypothalamic-pituitary adrenal (HPA) axis. HPA axis is the central coordinator of the mammalian neuroendocrine stress response systems comprises of endocrine hypothalamic components, including the anterior pituitary, an effector organ, and the adrenal glands (Sapolsky, 2004) [20].

Psychological effects cause of the neuro-endocrine mechanism for trauma

Vasterling & Brewin (2005) [25] theorized that significant levels of trauma exposure can permanently change functioning of HPA axis and amygdala. When this HPA axis functioning disrupts, automatically the sequence of CRH-ACTH-AVP and cortisol functioning gets disrupt, and this may results into the occurrence of psychological symptoms includes experience of cognitive and affect regulation difficulties, memory dysfunction, depression, anxiety, and other adverse health effects (Haglund, Nestadt, Cooper, Southwick, & Charney, 2007) [10]. Studies identified the most significant effect of disturbed HPA functioning is chronic social avoidance and defeat behaviors (Wood, Walker, Valention, & Bhatnagar, 2010) [29].

Explicit and spatial memories are also highly vulnerable to the long term exposure to trauma as sustained exposure to cortisol can produce adverse effects like reduction in dendritic branching, loss of dendritic spines, and also may kill the hippocampal neurons and make the hippocampus shrink and ultimately results in impairment in neurogenesis (Arborelius *et al.,* 1999; Fuchs, 2000; Nestler, 2002; Sherin, 2011) [3, 9, 15].

2. Neuro-chemical changes due to trauma:

The core neuro-chemicals which play a significant role in trauma exposure are catecholamines and serotonin.

Dopamine (DA) and norepinephrine (NE) are the two most important neuro-chemicals in the family of catecholamine (Sherin, 2011). Many researches has established the evidence in human beings when they face adverse circumstances or expose to stressors, it stimulates to release mesolimbic dopamine. Coming to the role of norepinephrine (NE), which releases from adrenal medulla is one of the prime coordinators of autonomic stress response. It deals with both the mechanisms of central and peripheral nervous systems and induces rapid physiological changes associated with anxious and arousal symptoms (Bremner, 1999) [7, 24]. Increased release of norepinephrine from sympathetic nerve endings cause changes in blood flow to a variet y of organs as needed for fight-or-flight response mechanism.

Serotonin (5-HT) is a monoamine neurotransmitter which is biochemically derived from tryptophan. Serotonin is a natural antidepressant and it is one of the natural defence mechanisms of the human body to fight back with traumatic experiences. It can be majorly found in the central nervous system, gastrointestinal tract and in blood as well. Serotonin mainly deals with regulation of sleep, mood and appetite. Chronic exposure to trauma leads to decrease in the levels of secretion of which eventually results in increased down regulation of serotonin (Devis *et al.,* 1999).

Psychological effects of neuro-chemical changes due to trauma

One of the most common features of victims of chronic trauma is elevated hyperactivity of the autonomic sympathetic branch of the autonomic nervous system (ANS). An elevated level of neuro-chemicals like catecholamine results in hyper vigilance and anxiety in the victim. Hypervigilance includes elevations in blood pressure, cardiac rate, and skin conductance (Vermetten, 2002) [26]. Heightened norepinephrine levels may cause enhanced encoding in memory for traumatic and aversive experiences. It subsequently leads to the re-experiencing symptoms such as flashbacks and nightmares (sowthwick, 1999). Though cortisol is protective in nature it can serve best only when it is in the proper levels in the human body. Hypercortisolism (presence of excessive amount of cortisol than required) may results in defeat responses, feelings of helplessness and hopelessness which finally leads to withdrawal symptoms. On the other hand, hypocortisolism (presence of less amount of cortisol than the required) at the time of trauma exposure might be a risk factor for maladaptive stress responses and predispose to future PTSD (Yehuda, 1998; Sherin, 2011) [30].

Increased serotonin causes the individual to experience impulsivity, hostility, aggression, depression, and suicidality. It also may results in disturbances in mood, insomnia, and loss of appetite (Ressler, 2000) [19]. Extended periods of trauma exposure results in decrement in the levels of serotonin or tryptophan (the chemical from which serotonin is made) it eventually causes to depression, anxiety, panic, hostility and sometimes obsessive compulsive disorders. In addition to these neuro-chemicals, traumatic exposure alters the other

chemicals in the body called peptides and amino acids. These alterations in the various bodily chemical levels also play role to some extent in learning and memory.

3. Neuro-anatomical changes due to psychological trauma

Neuroplasticity of the brain

Neuroplasticity is one of the brain's features to change its structure in response to environmental stimuli. Siegel hypothesized that the human brain is determined by both genetic information as well as the impact of the experience (Siegel, 2003) [20]. The threatening experiences not only have the power of demonstrating the psychological changes but also the neurobiological changes in the victim's body and hence this complex trauma symptoms and behaviours are deeply rooted in neurobiology of the victim. To understand this phenomenon in simple words, we can say that all the experiences we experience every minute are filtered by our senses and these sensory signals generate cellular and molecular processes in the brain. These processes alter the neurochemistry along with the cytoarchitecture of the brain which ultimately results in the structure and functioning of the brain. This is nothing but creating some internal representation of the external world. This entire process depends on the type, intensity and frequency of the experience one has. Bremner (2006) has hypothesized that psychological symptoms of trauma are manifestations of changes in brain structure and function due to the traumatic experiences and stress. The earlier during childhood the traumatic experience occurs, the more severe the effects on intracranial volumes (Gussie, 2005) [16].

According to Bruce Perry, 1995; though trauma is an experience, psychologists in the initial years strongly believed that it can alter the structure and function of the brain to some extent because brain is the part which processes and internalizes the traumatic experiences. Researches in the field also have been suggesting that psychological trauma can leads to neurobiological consequences. The technological advancements in the field of neurobiology in the recent times established the valid evidences to this concept which once was only a belief. Besides to the surgical and invasive techniques, many non invasive and technologically sophisticated methods emerged to understand the structure and functioning of the human brain which includes Positron Emission Tomography (PET), Functional Magnetic Resonance Imaging (fMRI), and Single Photon Emission Computed Tomography (SPECT) etc. In this paper, researcher tried to discuss the role of trauma in altering its structure and its effects on various parts of the brain. On the other hand this paper also concerned about the psychological effects of the anatomical changes due to exposure trauma.

The present study focused on the three major parts of the brain namely hippocampus, amygdala and prefrontal cortex.

A) Hyppocampus

The hippocampus is one of the most plastic or mouldable regions in the brain. Fuchs, in 2000 [9] experimented with animals in his laboratory and he subjected the animals to prolonged experience of stress. As mentioned above, it caused the damage to the hippocampus region, leading to reduction in dendritic branching, and loss of dendritic spines. Another study on Vietnam veterans with trauma demonstrated significant small hippocampus volume when compared to controls (Stein, 1997) [23]. Many other researchers also established the trauma and the reduction in the hippocampal volume (Bremner, Vythilingam, Vermetten, Southwick, McGlashan, Nazeer *et al.,* 2003; Villarreal *et al.,* 2002; winter and Irle, 2004) [4, 27, 28].

Decrement in the hippocampal volume leads to distortion and fragmentation of memories. Recent evidence also suggests that decreased hippocampal volumes might also be a predictor of possible PTSD.

B) Amygdala

Amygdala is one of the parts in limbic system and located in temporal lobes of the brain. The prime role of amygdala is to interpret the threatening stimuli and auqisition of fear responses whichever our body confronts with. Neuroimaging technology has proved that there is significantly increased functioning in the amygdale at the time of stress induced experiences (Protopopescu, 2005) [18]. A study carried out by Shin LM *et al.,* in 2006 [22] proved that trauma victims further show increased amygdala responses to general emotional stimuli even though they are not emotion provoking or trauma-associated.

This increased amygdala activity may leads to the oversensitivity towards fearful or emotion provoking conditions. It will make the individual more vulnerable to the psychological threats.

C) Prefrontal cortex

The medial PFC exerts inhibitory control over stress responses and emotional reactivity in part by its connections with the amygdala. Ordinarily this structure facilitates recall of the best action or emotional response to a given conflict while inhibiting amygdala reactivity (Hass-Cohen, 2014). But when it is to deal with the intrusive experiences, it cleary shows the diminishing effects on the part of the cognitive activity (Yehuda & LeDoux, 2007) [31]. A study conducted by Lanius, Frewen, *et al.,* in 2010 has demonstrated the hypoactivity in the prefrontal cortex region of the brain. Many other researchers also found the same sort of results after experimenting with the various samples such as war veterans, abused women, neglected children etc. (Shin *et al.,* 2004; Bremner &Vythilingam *et al.,* 2003; Kasai *et al.,* 2008;) [4]

The diminishing effect of activation and functioning of prefrontal cortex can lead to experience trouble in recalling and memory related issues. It also inhibits emotional reactivity to the stimuli.

Conclusion

Psychological trauma is one of the psychological problems with high prevalence rate in almost all the nooks of the world. Though the researcher divided the study into three parts to make it simple, it should be noted that these three (neuro-endocrinal, neuro-chemical and neuro-anatomical) are interrelated and demonstrates a chain reactions. One alteration in one system makes the changes in another system. Hence we cannot look at the functions of these three systems separately but all together could give a better understanding of what actually trauma can do to a person.

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