The Biology of Trauma

Implications for Treatment

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During the past 20 years, the development of brain imaging techniques and new biochemical approaches has led to increased understanding of the biological effects of psychological trauma. New hypotheses have been generated about brain development and the roots of antisocial behavior. We now understand that psychological trauma disrupts homeostasis and can cause both short- and long-term effects on many organs and systems of the body. Our expanding knowledge of the effects of trauma on the body has inspired new approaches to treating trauma survivors. Biologically informed therapy addresses the physiological effects of trauma, as well as cognitive distortions and maladaptive behaviors. The authors suggest that the most effective therapeutic innovation during the past 20 years for treating trauma survivors has been Eye Movement Desensitization and Reprocessing (EMDR), a therapeutic approach that focuses on resolving trauma using a combination of top-down (cognitive) and bottom-up (affect/body) processing.

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Both public and professional interest in the effects of trauma have greatly increased as we have experienced the worldwide proliferation of violence, including the terrorist attacks on September 11, 2001, in the United States, the train bombings in Spain in 2004, and escalation of armed conflict in many parts of the world including Afghanistan, Iraq, and other parts of the Middle East. During the past 20 years, with the help of more sophisticated research tools, we have begun to understand the biological basis of both trauma and violence. With the advent of brain imaging techniques and new biochemical approaches, we are beginning to comprehend the complexities of the rela-

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tionships among experience, neurophysiology, endocrinology, and behavior. As a result of this expanding knowledge, we have developed an appreciation for the widespread, long-term effects of psychological trauma on the body as well as the mind, and we are exploring new ways of effectively treating trauma survivors.

During the next 10 years, as we continue to study the development and neurophysiology of the brain, we will dramatically increase our understanding of how the brain is affected by trauma. We will learn more about the effects of psychological trauma on neurotransmitter receptors, synaptic connections, and hormone interactions and how those effects are translated into behavior. Based on our expanding understanding of the biology of trauma, we will continue to develop more effective treatment strategies.

Recent findings concerning the biology of trauma challenge clinicians to embrace treatment methods that address biological effects. Cognitive-behavioral therapy offers many strategies that are helpful in treating trauma survivors. However, trauma is far more than a cognitive issue. Traumatic experience is largely affective and somatic, and effective treatment must also address the body. The most promising methodological innovation in the past 20 years for the treatment of trauma has been Eye Movement Desensitization and Reprocessing (EMDR).

BIOLOGICAL EFFECTS OF TRAUMATIC STRESS

Traumatic experiences cause traumatic stress, which disrupts homeostasis. During the past few years, we have dramatically increased our understanding of the effects of traumatic stress on the brain, sympathetic nervous system, and endocrine system. Through a physiological domino effect, these changes affect many other body systems, including the cardiovascular system, respiratory system, and muscular system.

Some Effects of Traumatic Stress on the Endocrine System

The endocrine system works closely with the nervous system to regulate the body's physiology. Traumatic experience causes both immediate and long-term endocrine changes that affect metabolism and neurophysiology. The sympathetic nervous system is immediately affected by any perception of danger and signals the adrenal medulla to greatly increase its output of epinephrine and norepinephrine. These hormones rapidly affect many body systems leading to a fight-or-flight response. If neither response is possible, the person freezes.

During stress, the hypothalamic-pituitary-adrenal system is also activated, leading to increased levels of cortisol, a glucocorticoid released by the adrenal cortex that modulates the physiologic response to stress and helps activate effective coping strategies. Cortisol concentration has been the focus of several recent studies because abnormally high levels of cortisol, associated with stress, can damage neurons in the hippocampus.

Abnormal concentrations of adrenal hormones depress the immune system and contribute to the physiological hyperarousal (e.g., exaggerated startle response, hypervigilance) characteristic of PTSD. Chronic physiological hyperarousal makes it very difficult to regulate autonomic responses to internal or external signals and decreases the ability to respond appropriately to emotional signals (van der Kolk, 1996). In chronic stress and in Post-Traumatic Stress Disorder (PTSD), cortisol concentrations are lower than would be expected, and exposure to new stressors elicits lower levels of cortisol secretion.

Some Effects of Traumatic Stress on the Brain

Brain studies using functional magnetic resonance imaging (FMRI), positron emission tomography (PET), magnetic resonance spectroscopy (MRS), and electroencephalogram (EEG) allow researchers to study the brain in action (Villarreal & King, 2001). Using photon emission tomography (SPECT), neurobiologists can now analyze the density of brain receptors. Studies of the brains of human and animal subjects who have been victims of traumatic stress reveal differences in their brains when compared with control subjects who have not experienced trauma. These changes in brain structure and physiology are thought to affect memory, learning, ability to regulate affect, social development, and even moral development.

To understand the problems presented by traumatic memories, we will first review how nontraumatic memories are processed. Memories of ordinary experiences are temporarily stored in the limbic system as episodic memories, memories of personal experience and events. Episodic memories are autobiographical; they include a sense of time and self. Cognitive aspects are stored in the hippocampus and the associated emotion is stored in the amygdala. As the brain processes these memories over time, aspects of them are abstracted and transferred to the neocortex, particularly the association areas of the frontal lobes, for long-term storage. These memories are semantic, or factual, memories. (Episodic and semantic memories are two types of explicit memory.)

The memories of moderately disturbing experiences apparently remain in the right limbic system for a longer period of time than the memories of neutral events. We process disturbing memories by thinking, talking, and sometimes dreaming about the experience. As the brain slowly processes the memory, it is abstracted and transferred into the left neocortex where it is filed away along with other memories and becomes part of the narrative of one's life. The stored information can be retrieved when needed to understand future events.

Traumatic events overwhelm the brain's capacity to process information. The episodic memory of the experience may be dysfunctionally stored in the right limbic system indefinitely and may generate vivid images of the traumatic experience, terrifying thoughts, feelings, body sensations, sounds, and smells. Such unprocessed traumatic memories can cause cognitive and emotional looping, anxiety, PTSD, maladaptive coping strategies, depression, and many other psychological symptoms of distress. Because the episodic memory is not processed, a relevant semantic memory is not stored and the individual has difficulty using knowledge from the experience to guide future action.

Because traumatic experiences are terrifying, the survivor avoids thinking and talking about what happened. This avoidance prevents processing. Trauma alters physiology and gives rise to images, feelings, sensations, and beliefs that may persist throughout life. Only after the traumatic memory is fully processed and integrated can homeostasis be restored.

Traumatic memories can be triggered by stimuli that are in some way associated with the traumatic event. Terrifying memories, including the affect associated with them, may be reexperienced with their original intensity. Survivors feel the terror and may lose their sense of time and place. One client stated, "Part of me knows it's not really happening now, but it *feels so real* that I get mixed up."

Brain scan technology enables us to study the brain in action. Using PET scans, researchers have demonstrated some of the neurophysiological effects that take place when traumatic memory is triggered. In one study, participants were asked to write detailed narratives of their traumatic experience (Rauch et al., 1996). Then, each participant was asked to read the narrative during brain scanning. The results were dramatic. Activity increased in the right brain, primarily in the limbic system and in the visual cortex (the site of vivid images of the event). Activity decreased in the anterior cingulate cortex (ACC), which normally modulates the limbic system. Activity also decreased in Broca's area, an area of the brain important in semantic processing and articulation of language. This decrease in activity may be the neurophysiological basis for the "speechless terror" that many individuals experience both during a traumatic event and when processing trauma in therapy.

In the United States, child abuse and neglect are the most common causes of Type III trauma, extreme trauma characterized by multiple traumatic experiences that typically begin at an early age (Solomon & Heide, 1999). An infant's relationship with its primary caregiver has a direct effect on the hard wiring of neural circuits in the developing brain. Many of the neural circuits affected by early experience connect areas of the brain critical for emotional, physiological, psychological, and social development. Some of these circuits are necessary for adaptive coping in emotional and stressful situations (Schore, 2003).

The orbitofrontal cortex helps regulate emotional states and responses. By way of its connections with the hypothalamus and limbic system, it regulates autonomic responses to social stimuli and mediates emotionally "attuned communication." This part of the cortex helps us understand other people's emotional experience, enabling us to respond empathically, a capacity necessary for moral judgment. Normal development of the right brain and later emotional and social development depend on healthy attachment between infant and caregiver (Schore, 1994, 1996, 2003).

Children who are severely neglected experience chronic traumatic stress that compromises right brain development, resulting in neuron damage and atrophy. Impairment of the orbitofrontal cortex and the circuits connecting it with subcortical areas can diminish the child's sense of self, leading to disconnection from other people. Severely neglected children do not deal well with stress and do not develop the ability to regulate the intensity and duration of their affect (Schore, 2002; van der Kolk & Fisler, 1994). Because these children have difficulty understanding emotion expressed by other people, they may not develop empathy.

Many studies conclude that impaired development of the orbitofrontal cortex and its neural connections with the limbic system decreases capacity to regulate affect. For example, the orbitofrontal cortex normally inhibits areas in the hypothalamus that are associated with aggression and thus is central in the regulation of aggressive impulses. Abnormal development of the neural circuits linking the orbitofrontal cortex and ACC with the amygdala interferes with normal inhibition of rage responses. Without the normal cortical modulating effect, the amygdala's responses are exaggerated. When aggressive impulses are not inhibited, an individual may act out violently. This lack of inhibition is part of the pattern of sociopathy (Best, Williams, & Coccaro, 2002; Schore, 2003). Studies suggest that trauma caused by neglect and abuse can lead to antisocial behavior (Heide, 1992, 1999).

Many long-term changes in the brain have been associated with Type III trauma, including abnormal concentrations of certain neurotransmitters, changes in EEG patterns, and a decrease in integration between right and left hemispheres. Measurable size decreases have been found in the cerebral volume, the corpus callosum, amygdala, and hippocampus. Whether or not these changes are reversible with treatment is an important question for future study.

BIOLOGICALLY INFORMED TREATMENT

> I'm 44 years old and I've been to at least eight therapists since I was abducted and raped at age 15. I've talked about it over and over. . . . I'm *tired* of talking about it . . . and it's still here . . . still affecting my life. I just want to move past it. . . . I want to feel better.

Many trauma survivors share Debbie's experience in therapy—and her frustration. Talking alone doesn't make "it" go away. Consequently, as our understanding of the biological nature of trauma has increased over the past several years, many therapists have modified their treatment approach.

Most traditional therapies, including cognitive-behavioral therapy (CBT), depend on top-down processing in which the client is taught to use cognitive strategies to manage or inhibit problematic feelings, thoughts, and behaviors (the neocortex rules the body). For example, CBT helps clients understand how traumatic experience has affected them and helps them change erroneous beliefs or maladaptive ways of thinking or behaving. This approach helps clients gain insight into their way of being in the world. Clients may learn to identify stimuli that trigger them and understand their responses. They may learn to manage disturbing emotions and body sensations. Top-down approaches, however, do not process the episodic memories or resolve physiological hyperarousal. Consequently, clients are still triggered by stimuli that their limbic systems perceive as dangerous and they may still respond in maladaptive ways. Even with years of therapy, immediate responses to triggering stimuli tend to be physiological rather than logical.

Biologically informed therapy focuses on processing traumatic experience. Episodic memories are processed and information transferred from the limbic system to the neocortex and filed away along with other narrative memories. Biologically informed therapy includes bottom-up processing, which focuses on what is going on in the body. This approach helps clients connect with their bodies and with their feelings. It facilitates their learning to tolerate intense feelings and to release emotion appropriately. Survivors learn to calm their physiology.

Eye Movement Desensitization and Reprocessing

Although several treatment approaches have been developed that focus on the biological aspects of trauma recovery, we focus here on Eye Movement Desensitization and Reprocessing (EMDR) because its effectiveness has been demonstrated by several empirical studies (Servan-Schreiber, 2000; Shapiro, 1999). EMDR is an effective combination of body-focused (bottom-up processing) and cognitive-behavioral (top-down processing) treatment. Developed by psychologist Francine Shapiro during the 1990s, EMDR helps the trauma survivor access and process traumatic memories so that they can be brought to an adaptive resolution (Shapiro, 2001).

During EMDR, which uses structured protocols, the client is asked to identify a disturbing image that represents the worst part of the traumatic event and to identify negative beliefs about self stemming from the experience. The therapist asks the client to formulate a positive cognition that could replace the negative belief and then to notice the feelings and body sensations associated with the disturbing memory/image. The client is instructed to hold the disturbing event/image in mind along with the associated negative belief, feelings, and sensations in the body while focusing on an external stimulus.

The client is asked to track the therapist's moving fingers/hand back and forth in front of his or her visual field for about 20 to 50 seconds. After each set of bilateral stimulation, the client is asked what comes up or what changes his or her experiences. Rating scales are used throughout each session to document changes in the intensity of feelings and body sensations. Eye movement can be replaced by alternating right-left tactile stimuli (e.g., alternately tapping right and left hands) or by alternating right-left tones. As the client focuses on the traumatic experience and associated negative beliefs, feelings, and sensations, the episodic memory is processed and consolidated as a narrative memory bringing the client to an adaptive resolution.

Cognitive components of the EMDR protocol include asking the client to develop positive cognitions/antidotes for negative self-beliefs. (This is a form of cognitive restructuring in which the client replaces negative, psychologically unhealthy beliefs with more adaptive beliefs.) In the EMDR strategy referred to as the "cognitive interweave," the therapist cognitively assists a client who is looping or who lacks necessary information. The client also learns containment strategies for managing intense feelings, for example, learning to shift out of anxiety or intense affect by going to a safe place (beach, mountain, lake) in his or her mind.

The neurophysiological basis of EMDR is not known with certainty, but several hypotheses have been suggested. In EMDR, visual, tactile, or auditory stimuli alternately stimulate right and left sides of the brain, forcing a shift of attention across the midline. Stickgold (2002) hypothesized that the repetitive redirecting of attention in EMDR induces a REM sleep-like state, a neurobiological state that facilitates the activation of episodic memories. These memories are processed and integrated into neural networks in the neocortex as semantic (narrative) memory. The work of Christman and Garvey (Christman, Garvey, Propper, & Phaneuf, 2003) supports Stickgold's hypothesis. These researchers found that alternating eye movements enhanced episodic memory retrieval tasks but not narrative memory retrieval tasks.

In one very interesting study, SPECT scans were administered before and after EMDR treatment for six PTSD participants who each received three EMDR sessions (Levin, Lazrove, & van der Kolk, 1999). The investigators reported an increase in bilateral activity in the ACC, a part of the brain that modulates the limbic system and helps us distinguish real from perceived (but not real) threat. The increase in ACC activity suggests a decrease in hypervigilance. These researchers also found an increase in prefrontal lobe metabolism, suggesting greater ability to make sense of incoming sensory stimulation.

Advances in science in the 21st century are confirming what Freud suggested nearly 100 years ago. Behavior is more than psychologically determined. Human development, including behavior, is biologically guided. In contrast to Freud's thinking, however, the latest findings with respect to human trauma suggest that individuals can gain mastery over their destiny by participating in therapeutic strategies that consider both the biological and psychological roots of human development. EMDR is an effective treatment modality that considers both. A 38-year-old trauma survivor described her experience with EMDR as follows:

I feel myself shifting. For the first time, I'm paying as much attention to dealing with my life as it is now, as to dealing with my life as it was back then.

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