TRAUMA & MEMORY

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Traumatic Memories Lost and Found

Can Lost Memories of Abuse Be Found in the Brain?

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Inscribed over the door of the Jewish Holocaust Museum in New York City is the motto "Never Forget." This is the credo of many witnesses and survivors of traumatic events, which reflects the feeling that the sufferings and loss of others who were victims of traumatic experiences should not be allowed to lapse into the shadows of lost remembrance. This credo is paradoxical, and perhaps even tragic, in the face of the reality of the fate of many traumatic memories. These memories are subject to fragmentation and to a loss of the sense of context of the memories in space and time. In many cases, memories can be just outside of conscious awareness for many years, before specific cues or triggers bring them back into consciousness in full force, with all of the negative thoughts and emotions associated with the original events. Some of these memories, on the other hand, may be permanently sealed from resurrection by the conscious mind.

There is, in fact, considerable controversy now about the validity of delayed recall of traumatic events, such as childhood abuse (Loftus, Garry, & Feldman, 1994; Loftus, Polonsky, & Fullilove, 1994; Williams, 1994a, 1994b). Until recently, there has been little solid evidence upon which to base an opinion about this issue. Most studies have been performed by cognitive psychologists in populations of normal human subjects. These studies have provided evidence for the idea that memory is subject to distortion or postencoding modification. For example, in a typical study, subjects were shown a series of slides that told a story involving a stop sign. These slides were followed by the reading of a similar verbal narrative in which the reference to the stop sign was replaced by a reference to a yield sign. When subjects were tested on recall of material related to the slides, they were more likely to report (incorrectly) having seen a yield sign than did subjects who did not receive the

misleading information. The researchers who conducted this study concluded that misleading information led to "overwriting" of the original memory trace (Loftus, Miller, & Burns, 1978). These findings have been quoted in support of the idea that delayed recall of episodes of childhood abuse is often due to "false memory," or suggestibility effects, propagated by overzealous psychotherapists.

Other studies have suggested that this phenomenon is due to a source amnesia effect—that is, subjects do not have an overwriting of the memory; rather, they do not remember where they obtained the information (Lindsay & Johnson, 1989). For instance, in one study, subjects were assessed with a test in which they saw slides that included a hammer, followed by misleading verbal information involving a screwdriver, and then a forced-choice test of what they had seen in the slides between a hammer and an item to which they had previously not been exposed (a wrench). The researchers argue that if there is a true overwriting phenomenon with misleading verbal material, then subjects exposed to misleading information should have a decrement in recall in comparison with subjects who have not previously been exposed to such information (McCloskey & Zaragoza, 1985). They found no decrement in recall in this paradigm in subjects for whom the misleading item was not one of the possible choices in the forced-choice test of recall.

The studies described above, as well as other studies, have raised doubts about the degree to which traumatic memories are susceptible to distortion due to misleading and suggestive statements (as may occur during psychotherapy). Recent findings also suggest that stress itself can lead to modifications in memory traces.

The Effects of Stress on Memory in Normal Human Subjects

☐ Stress exposure results in alterations in the laying down of memory in normal human subjects. The assassination of President Kennedy raised the observation that most people have an enhanced awareness of where they were and what they were doing at the time they received news of this event. This led to the "flashbulb" hypothesis, formulated by Brown and Kulik (1977): Certain events that are surprising and consequential (emotionally charged) lead to an enhancement of memory for personal circumstances surrounding the event. These include such facts as what the person was wearing and what he or she was doing at the time (Bohannon, 1988; Bohannon & Symons, 1992). Studies involving exposure of subjects to traumatic slides involving injury or threat have found enhanced recall of central details of the slides, and reduced recall of peripheral details, in comparison with neutral slides (Christianson & Loftus, 1987, 1991). In children, the stress of inoculation has also been associated with relative enhancement of memory for central details related to the procedure (Goodman, Hirschman, Hepps, & Rudy, 1991). In summary, the findings are consistent with an enhancing effect of stress on memory, especially recall for central details.

Neuroanatomical Correlates of Memory

☐ Studies in normal human subjects may not be applicable to victims of extreme trauma, such as childhood abuse. In order to understand this population better, it is useful to look at findings related to the long-term effects of extreme stress on memory function (Bremner, Krystal, Charney, & Southwick, 1996a, 1996b; Bremner, Krystal, Southwick, & Charney, 1995). Memory formation involves encoding (the initial laying down of the memory trace), storage (or consolidation), and retrieval. Consolidation occurs over several weeks or more, during which time the memory trace is susceptible to modification. Explicit (or declarative) memory includes free recall of facts and lists, and working memory. In contrast, implicit memory is demonstrated only through tasks or skills in which the knowledge is embedded, or through phenomena such as conditioning.

Memory is mediated by several connected subcortical and cortical brain regions (reviewed in Schacter & Tulving, 1994). The hippocam-

pus plays an important role in explicit memory. Studies showed deficits in explicit memory following lesions of the hippocampal formation (dentate gyrus, hippocampus proper, subicular complex, and entorhinal cortex), amygdala, and surrounding perirhinal and parahippocampal cortices (Mishkin, 1978; Murray & Mishkin, 1986; Zola-Morgan, Squire, & Amaral, 1989; Zola-Morgan, Squire, Amaral, & Suzuki, 1989). These findings have been confirmed in human subjects, as in the case of H.M., who suffered from a bilateral stroke involving these structures (Scoville & Milner, 1957). The hippocampus also plays a role in the fear responding to the context of a situation. In animals, exposure to a testing box from which electric shock was previously administered will result in a "freezing" response (which is characteristic of fear), even in the absence of the shock. Lesions of the hippocampus interfere with acquisition of conditioned emotional responses to the context in which the shock took place (Kim & Fanselow, 1992; Phillips & LeDoux, 1992). The thalamus, in addition to being a gateway for sensory information to be relayed to cortex and other regions, is involved in explicit memory. Dorsolateral prefrontal cortex (middle frontal gyrus) is involved in working memory (Goldman-Rakic, 1988). *Working memory* refers to the ability to store information in a visual or verbal buffer while performing a particular operation utilizing that information.

The anteromedial (or ventromesial) prefrontal cortex includes the anterior cingulate gyrus and is functionally and anatomically distinct from the dorsolateral prefrontal cortex. In the late 19th century, the famous patient Phineas Gage had a projectile metal spike pass through his frontal cortex, with damage specifically to the anterior cingulate, anteromedial prefrontal cortex, and parts of the orbitofrontal cortex. Following the accident, the patient had normal memory recall and cognitive function, but his behavior deteriorated to irresponsibility, profanity, and lack of social conventions, which indicated a deficit in the planning and execution of socially suitable behavior, suggesting a role for the anteromedial frontal cortex (including anterior cingulate) in these behaviors (Damasio, Grabowski, Frank, Galaburda, & Damasio, 1994). The orbitofrontal cortex is the primary sensory cortical area for smell, and it plays a role in the fear response, extinction to fear (Morgan & LeDoux, 1994), and certain types of memory. Parietal cortex is involved in spatial memory and attention.

The amygdala is an important mediator of emotional memory. The paradigm of conditioned fear has been utilized as an animal model for stress-induced abnormalities of emotional memory (Davis, 1992). In the fear-potentiated startle paradigm, a normally neutral stimulus (something that typically has no effect on the animal), such as a bright light, is paired with an aversive stimulus, such as electric shock. With repetitive pairing of the light and the shock, a learning process occurs (conditioning) in which the light alone eventually causes an increase in the startle response (referred to as *fear-potentiated startle*). The shock in this example is termed the *unconditioned* stimulus, because no training was required for it to have the effect of potentiating startle, whereas the light is referred to as the *conditioned* stimulus, as the training trials pairing it with the shock were required for it to develop the capacity for potentiating the startle response. Lesions of the central nucleus of the amygdala eliminate the conditioned fear response (Hitchcock & Davis, 1986; Hitchcock, Sananes, & Davis, 1989), whereas electrical stimulation of the central nucleus increases acoustic startle (Rosen & Davis, 1988), confirming the important role that this structure plays in this phenomenon.

Explicit memory formation is not instantaneous. After the laying down of the original memory trace, consolidation—a process that lasts from weeks to months—occurs, during which the stored memory is subject to modification or deletion (Squire, Slater, & Chace, 1975). Although the hippocampus and adjacent structures are important in encoding and retrieval, they do not play a major role in the long-term storage of explicit memory (Zola-Morgan & Squire, 1990). The evidence is consistent with the fact that memories are stored in the primary neocortical sensory and motor areas and later evoked in those same cortical areas. It has been hypothesized that the role of the hippocampus is to bring together memory elements

from diverse neocortical areas at the time of retrieval of explicit memory (Zola-Morgan & Squire, 1990).

Neuroanatomical Correlates of the Effects of Stress on Memory: Relevance to a Model for Delayed Recall of Childhood Abuse

☐ Brain regions involved in memory also play a prominent role in the execution of the stress response. In the early part of the 20th century, the observation was made that with the removal of the cerebral cortex, a hyperexcitability of anger termed *shame rage* developed (Cannon, 1931). Animals in the shame rage state were quick to attack and behaved as if they were experiencing a profoundly threatening situation. Papez (1937) proposed that hypothalamus, thalamus, hippocampus, and cingulate are responsible for the behaviors of the decorticate cat. Kluver and Bucy (1937) noted that removal of the temporal lobe (including hippocampus and amygdala) resulted in the absence of anger and fear. These observations led to the development of the concept of the limbic brain, in which the brain regions listed above (and others, including orbitofrontal cortex) mediate the stress response and emotionality (MacLean, 1949).

Stress has long-term effects on these brain regions, which are involved in memory, emotionality, and the fear response (Bremner, Krystal, Charney, & Southwick, 1996; Bremner, Krystal, et al., 1995; Pitman, 1989). Monkeys who died spontaneously following exposure to severe stress (due to improper caging and overcrowding) were found, on autopsy, to have multiple gastric ulcers, consistent with exposure to chronic stress, and hyperplastic adrenal cortices, consistent with sustained glucocorticoid release (Uno, Tarara, Else, Suleman, & Sapolsky, 1989). They also evidenced damage to the CA2 and CA3 subfields of the hippocampus. Follow-up studies suggested that hippocampal damage is associated with direct exposure of glucocorticoids to the hippocampus (Sapolsky, Uno, Rebert, & Finch, 1990). Studies in a variety of animal species have shown that direct glucocorticoid exposure results in a loss of pyramidal neurons (Sapolsky, Krey, & McEwen, 1985) and dendritic branching (Wooley, Gould, & McEwen, 1990) that are steroid and tissue specific (Packan & Sapolsky, 1990). Glucocorticoids appear to exert their effect by increasing the vulnerability of hippocampal neurons to endogenously released excitatory amino acids (Sapolsky & Pulsinelli, 1985). These effects of cortisol on hippocampal neurons are associated with deficits in memory function (Luine, Villages, Martinex, & McEwen, 1994).

Traumatic stress has long-term effects on memory function in human populations as well as in animals. These effects may provide a rationale for delayed recall of abuse in traumatized individuals suffering from neuropsychiatric disorders such as posttraumatic stress disorder (PTSD). Empirical studies using reliable and valid instruments have documented that the symptom of dissociative amnesia is strongly related to the diagnosis of PTSD in highly traumatized populations, such as Vietnam combat veterans (Bremner, Steinberg, Southwick, Johnson, & Charney, 1993). Amnesia involves gaps in memory lasting from minutes to hours or days. These episodes can include such things as driving on the highway and suddenly noticing that 3 hours have passed or suddenly finding oneself in a new city and having no idea how one got there. Dissociative amnesia may also include absent recall of episodes of childhood sexual abuse. Evidence is also consistent with abnormalities of verbal memory as measured with standardized neuropsychological testing. We have measured explicit memory function with the Wechsler Memory Scale (WMS)-Logical (verbal memory) and -Figural (visual memory) components in Vietnam combat veterans with PTSD ($N = 26$) and controls matched for factors that could affect memory function ($N = 15$). PTSD patients had a significant decrease in free verbal recall (explicit memory) as measured by the WMS-Logical component, without deficits in IQ, as measured by the Wechsler Adult Intelligence Scale-Revised (Bremner, Scott, et al., 1993). PTSD patients also had deficits in explicit recall, as measured with the Selective Reminding Test, for both verbal and

Table 17.1 Neural Mechanisms and Brain Regions Involved in Delayed Recall of Childhood Abuse

Neural Mechanism	*Brain Region*	*Mechanism in Delayed Recall*
Retrieval deficits	hippocampus	inability to retrieve traumatic memories
Fragmented recall	hippocampus, neocortex	distortion of traumatic memories; inability to localize memories to actual abuse events
Conditioned fear	amygdala	avoidance of traumatic cues leads to decreased recall
Failure of extinction	orbitofrontal cortex	increased fear responding due to failure of extinction leads to avoidance of traumatic cues, decreased recall
Sensitization	hippocampus locus coeruleus	increased responsiveness to stressors leads to avoidance of stimuli, decreased recall
Neuromodulation of memory	multiple	long-term changes in neuromodulators with chronic stress lead to altered encoding and retrieval
State-dependent memory	multiple	"excessive" emotions required for retrieval of memories encoded in exceptional circumstances

visual components. We have subsequently found deficits in explicit memory tasks of free verbal recall measured by the WMS-Logical component in adult survivors of childhood abuse seeking treatment for psychiatric disorders (Bremner, Randall, et al., 1995). Studies have found deficits in explicit short-term memory as assessed with the Auditory Verbal Learning Test in Vietnam combat veterans with PTSD in comparison with National Guard veterans without PTSD (Uddo, Vasterling, Brailey, & Sutker, 1993) and the California New Learning Test in Vietnam veterans with combat-related PTSD in comparison with controls (Yehuda et al., 1995).

These verbal memory deficits were associated with reductions in volume of the hippocampus. As reviewed above, increased circulating glucocorticoids appear to be toxic to the hippocampus. We compared hippocampal volume measured with MRI in Vietnam combat veterans with PTSD ($N = 26$) and healthy subjects ($N = 22$) matched for factors that may affect hippocampal volume, including age, sex, race, years of education, height, weight, handedness, and years of alcohol abuse. Patients with combat-related PTSD had an 8% decrease in right hippocampal volume in comparison with controls ($p < .05$), but there was no significant decrease in volume of comparison structures, including temporal lobe and caudate. Deficits in free verbal recall (explicit memory) as measured by the WMS-Logical component, percentage retention, were associated with decreased right hippocampal volume in the PTSD patients ($r = 0.64$; $p < .05$). There was no significant difference between PTSD patients and controls in left hippocampal volume, or in volume of the comparison regions measured in this study, left or right caudate and temporal lobe volume (minus hippocampus) (141). Patients with severe childhood physical and/or sexual abuse-related PTSD ($N = 17$) had a statistically significant 12% decrease in left hippocampal volume in relation to 17 controls matched on a case-by-case basis with the patients (Bremner, Randall, et al., 1997). These studies support preclinical findings of stress-induced damage to the hippocampus with associated memory deficits.

Deficits in hippocampal function may lead to alterations in recall of events of childhood abuse in patients with PTSD. The hippocampus has been hypothesized to play a role in the

integration of memory elements at the time of recall, and in placing events in space and time (Nadel & Willner, 1980). We have hypothesized that hippocampal dysfunction in trauma survivors with PTSD may lead to the following: a fragmentation of traumatic memories, an inability to place these memories in space and time, and deficits in retrieval that lead to delayed recall (Bremner, Krystal, et al., 1995). For instance, if a woman was locked in a closet as a child for many hours, she may recall the sound of a clock (outside the closet) and the subjective sense of fear, but she may have no other recall related to the event. Or she may recall only the smell of clothes (on the floor of the closet). Smelling something similar may later trigger a flooded recall of the entire event, with all of its negative emotionality. Facilitating associations in a comfortable and "safe" environment may also facilitate recall, leading to the appearance that delayed recall occurs only during psychotherapy. Stress-induced hippocampal dysfunction may also be involved in the phenomenon of dissociative amnesia, which essentially involves a loss of the normal context of space and time for specific memory traces.

The amygdala places the emotional valence on a memory trace, a crucial aspect of memories for childhood traumatic events. The paradigm of conditioned fear has been used to study function of the amygdala and emotional memory. Conditioned fear reactions characterize many of the abnormalities in responsiveness of PTSD patients, and may explain delayed recall of events of childhood abuse. Due to the conditioned fear effect, exposure to cues related to the original traumatic event is associated with intense negative emotional responding. The lives of particular patients may become highly irregular as these individuals attempt to develop patterns of behavior that are most likely to avoid traumatic cues. For instance, some PTSD patients refuse to answer the telephone, giving the rationale that (because bad news is usually communicated by telephone) if you don't answer the phone, you won't receive any bad news. It is also common for PTSD patients to exhibit behaviors such as not leaving the house, in order to avoid cues to recall, which may include relatively innocuous events. The purpose of such behaviors may not be within the individual's conscious awareness. Avoidance of traumatic cues also has the effect of decreasing associations to traumatic events. This leads to the traumatic memory becoming, in effect, "walled off" from other normal memories. Traumatic events of childhood are also not a part of normal life; many individuals may never have verbalized their experiences at any time in their lives. This adds to the paucity of associations between these events and ordinary cues to recall. It may take an unusual situation to cue recall of a traumatic childhood event that has been subject to these types of influences.

Other neural mechanisms, such as stress sensitization, may explain delayed recall of childhood abuse. *Stress sensitization* refers to the phenomenon in which repeated exposure to a stressor results in an amplification of responsiveness to subsequent stressors. For example, acute stress results in an increased release of norepinephrine in the hippocampus as well as other brain regions. Animals with histories of exposure to prior stressors become sensitized to exposure to subsequent stressors, so that there is an accentuation of norepinephrine release in the hippocampus with a subsequent stressor (Abercrombie, Keller, & Zigmond, 1988), which may modulate memory formation and retrieval. This raises the possibility that stress sensitization, acting through neuromodulators such as norepinephrine, may be associated with alteration in memory encoding and retrieval, which, as discussed above, may have implications for our understanding of the mechanisms of delayed recall in PTSD.

Stress sensitization has clinical applications for PTSD. We have found that exposure to the stressor of childhood physical abuse increases the risk for development of combat-related PTSD (Bremner, Southwick, et al., 1993). Israeli veterans with histories of previous combat-related acute stress reactions have been found to be at increased risk for reactivation of combat-related stress reactions in comparison with combat veterans without histories of stress reactions in response to combat (Solomon, Garb, Bleich, & Grupper, 1987). There are also other examples of how a history of exposure to prior stress increases the risk for stress-related symp-

tomatology upon reexposure to stressors (reviewed in Bremner, Southwick, & Charney, 1994).

Other brain regions, such as the orbitofrontal cortex, are also involved in emotional memory, and probably play a role in phenomena such as delayed recall of childhood abuse. Studies of human patients with brain lesions have shown that lesions of the orbitofrontal cortex result in symptoms of intense fear during seizures. In addition, some patients have been observed to experience visual hallucinations during seizures (Goldensohn, 1992). Some case reports have described a relationship between damage to the orbitofrontal cortex and visual hallucinations that appear to be similar to the flashbacks that are characteristic of PTSD (Fornazzari, Farcnik, Smith, Heasman, & Ichise, 1992). Yohimbine is an alpha-2 noradrenergic antagonist that causes an increase in brain norepinephrine release and increased symptoms of PTSD (Southwick et al., 1993). We have found a differential response of cerebral metabolism in PTSD patients and controls following administration of yohimbine as assessed by PET [^{18}F]2-fluoro-2-deoxyglucose (FDG). Patients showed a relative decrease with yohimbine, in comparison with controls (Bremner, Innis, et al., 1997). The greatest magnitude of difference was seen in the orbitofrontal cortex: Patients showed slight decreases in metabolism with yohimbine, and controls showed significant increases. Differences were also seen in prefrontal, temporal, and parietal cortex. PTSD is hypothesized to be associated with an increase in noradrenergic activity (reviewed in Bremner, Krystal, Charney, & Southwick, 1996; Bremner, Krystal, Southwick, & Charney, 1996b), and norepinephrine has a dose-dependent effect on neocortical metabolism, with high levels resulting in a decrease in metabolism and low levels resulting in increased metabolism. Our PET findings are therefore consistent with increased noradrenergic activity in PTSD. We also used PET $H_2[^{15}O]$ (radiolabeled water) to compare brain blood flow response to combat-related slides and sounds and neutral slides and sounds in Vietnam combat veterans with PTSD ($N = 10$) and combat veterans without PTSD ($N = 10$). The data were analyzed using statistical parametric mapping (SPM95). We found relatively greater increases in blood flow in PTSD patients in comparison with controls with combat slides and sounds in left parietal cortex, left motor cortex, dorsal pons, right lingual gyrus (posterior parahippocampus), and mid-cingulate ($z > 3.00$, $p < .001$). These regions are involved in spatial and motor memory and emotion. Non-PTSD veterans (but not PTSD veterans) activated orbitofrontal cortex with traumatic cues (Bremner et al., unpublished data, 1998). Other PET $H_2[^{15}O]$ studies using trauma-related scripts in PTSD patients found increased blood flow in right temporal lobe and insula, visual association cortex, orbitofrontal cortex, and anterior cingulate, with decreased blood flow in left inferior frontal and middle temporal cortex, although this study did not include a control group (Rauch et al., 1996).

In our studies, the failure of orbitofrontal cortex activation in PTSD patients, seen in the cognitive and pharmacological stress challenges, suggests a possible neuroanatomical correlate of the failure of extinction to fear, a typical manifestation of PTSD. In the conditioned fear paradigm, repeated pairing of a light (conditioned stimulus) with a shock (unconditioned stimulus) leads to an increase in fear responding to the light alone. With repeated presentation of the light alone, however, the fear responding gradually diminishes over time, a phenomenon known as extinction. The mechanism of extinction involves orbitofrontal inhibition of amygdala function. This has led us to hypothesize that a failure in orbitofrontal function in PTSD may lead to the failure of extinction, which is a prominent part of these patients' clinical presentation (Bremner, Krystal, et al., 1995), a hypothesis supported by our PET studies. Victims of childhood abuse clinically exhibit a failure of extinction to trauma-related stimuli. For instance, an individual who was locked in a closet may continue to show anxiety reactions when he is in a close space, even when there is no real threat of danger. A failure of extinction may act in a similar fashion to conditioned fear responses in PTSD, to modulate patient behavior to avoid cues to recall of the original traumatic childhood event. This often subconscious behavior is in the service of

avoiding recall of traumatic events associated with extremely negative emotionality, in part due to the failure of extinction to fear in these patients.

Neurotransmitters and neuropeptides released during stress have a modulatory effect on memory function. Several neurotransmitters and neuropeptides that have effects on learning and memory are released during stress, including norepinephrine, epinephrine, adrenocorticotropic hormone, glucocorticoids, corticotropin releasing factor (CRF), opioid peptides, endogenous benzodiazepines, dopamine, vasopressin, and oxytocin (De Wied & Croiset, 1991). Brain regions involved in memory, including hippocampus and adjacent cortex, amygdala, and prefrontal cortex, are richly innervated by these neurotransmitters and neuropeptides. These neuromodulators act at the level of the hippocampus, amygdala, and other brain regions involved in memory. Chronic abnormalities in the function of these neurotransmitter and neuropeptide systems in PTSD may contribute to the abnormalities in memory seen in these patients. For example, vasopressin has been shown to facilitate traumatic recall in patients with PTSD (Pitman, Orr, & Lasko, 1993). We have found elevated levels of CRF in the cerebrospinal fluid of patients with PTSD relative to healthy controls (Bremner, Licinio, et al., 1997). Exposure to subsequent stressors could also be associated with altered release of neuromodulators, resulting in altered memory recall in PTSD patients. Dysfunction in neuromodulators of memory in PTSD patients may lead to altered encoding—or retrieval—of traumatic childhood memories, leading to phenomena such as delayed recall of episodes of childhood abuse.

Mechanisms involving state-dependent recall may also be applicable to delayed recall of abuse (Bower, 1981). *State-dependent recall* refers to the phenomenon in which a similar affective state to the time of encoding leads to facilitation of memory retrieval. For instance, memories that were encoded during a state of sadness will have facilitated retrieval during similar states of sadness. Similar situations can occur for other emotional states. To extend this concept to victims of abuse, it can be seen that particular emotions tend to predominate at the time of the original abuse, such as extreme fear or sadness. These emotional states occur infrequently during routine adult lives, which are typically free of traumatic stressors. The recurrence of the state of extreme fear or sadness that occurred during the original abuse during psychotherapy or with exposure to a subsequent stressor may lead to delayed recall of the original abuse experiences. A clinical example of this would be the victim of sexual abuse who has no recall of her sexual abuse experiences until subsequent victimization by rape as an adult, leading to a recall of the original trauma.

Conclusion

☐ In this chapter I have attempted to address the paradox of "Never Forget" in trauma survivors in the face of the loss of memories of childhood abuse in patients with PTSD. I have asked whether memories of childhood trauma not easily available to consciousness can be found in the brain. It is clear that memory function and the brain regions that mediate memory differ between the chronically stressed individual and the normal individual. These differences may be invoked to provide a rationale for delayed recall of childhood abuse. There are also several phenomena and mechanisms that may explain delayed recall of abuse. For instance, there is mounting evidence for deficits in hippocampal function and structure in PTSD. Because the hippocampus is thought to be involved in memory recall and the placing of memories in space and time, it has been hypothesized that hippocampal dysfunction is involved in memory fragmentation and delayed or impaired recall in PTSD patients. There is a wealth of evidence in animal studies for abnormalities in conditioned fear responding and amygdala function with stress. Conditioned fear may lead PTSD patients to avoid traumatic cues (unconsciously), in order to avoid the extreme negative emotionality associated with such cues. In a similar fashion, failure of extinction and sensitization may lead to negative emotionality with cue exposure, which leads to avoidance behaviors. This may "wall off" trau-

matic memories, creating few associations to the event and making cues for recall rare.

Other concepts also provide potential explanations for delayed recall of memories of childhood abuse. These include state-dependent memory and modulation of memory traces during and after encoding by neurotransmitters and neuropeptides, which are released in high levels during stress. These mechanisms are probably applicable only to patients with disorders such as PTSD secondary to abuse. They probably are not pertinent to the entire range of individuals who are exposed to childhood abuse, including those who do not develop abuse-related psychiatric disorders.

This review has not provided a comprehensive analysis that can set to rest the controversy over delayed recall of childhood abuse. Rather, I have attempted to outline neural mechanisms that are known to be operative in situations of extreme stress and that may provide explanations for delayed recall of childhood abuse. Hopefully, future research work in this area will provide answers to some of the questions this controversy has raised.

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