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Childhood Trauma, the Neurobiology of Adaptation, and "Use-dependent" Development of the Brain: How "States" Become "Traits"

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ABSTRACT: Childhood trauma has profound impact on the emotional, behavioral, cognitive, social, and physical functioning of children. Developmental experiences determine the organizational and functional status of the mature brain. The impact of *traumatic* experiences on the development and function of the brain are discussed in context of basic principles of neurodevelopment. There are various adaptive mental and physical responses to trauma, including physiological hyperarousal and dissociation. Because the developing brain organizes and internalizes new information in a use-dependent fashion, the more a child is in a state of hyperarousal or dissociation, the more likely they are to have neuropsychiatric symptoms following trauma. The acute adaptive states, when they persist, can become maladaptive traits. The clinical implications of this new neurodevelopmental conceptualization of childhood trauma are discussed.

RÉSUMÉ: Le trauma de l'enfance a un impact profond sur le fonctionnement émotionnel, comportemental, cognitif, social et physique des enfants. Les expériences en matière de développement déterminent l'organisation et le fonctionnement du cerveau arrivé à maturité. L'impact d'expériences *traumatiques* sur le développement et le fonctionnement du cerveau sont discutés dans le contexte de principes de bases de neurodéveloppement. Il existe plusieurs résponses mentales et physiques d'adaptation au trauma, parmi lesquelles l'excitation physique intense et de la dissociation. Parce que le cerveau qui se développe organise et internalise les nouvelles "informations" d'une manière liée à l'utilisation et en dépendant, plus un enfant se trouve dans un état d'excitation ou de dissociation et plus il risque d'y avoir des symptômes neuropsychiatriques après le trauma. L'"état" adaptatif aigu peut devenir persistent et conduire à des "traits" d'inadaptation. Les implications cliniques de cette nouvelle conceptualisation de neurodéveloppement du trauma de l'enfance sont discutées.

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RESUMEN: El trauma de la niñez tiene un impacto profundo en el funcionamiento emocional, de conducta, cognitivo, social y físico de los niños. Las experiencias en el desarrollo determinan la condición funcional y de organización de un cerebro maduro. Se discute el impacto de las experiencias traumáticas en el desarrollo y el funcionamiento del cerebro en el contexto de los principios básicos del neurodesarrollo. Hay varias respuestas mentales y físicas que se adaptan con respecto al trauma, incluyendo el hiperdespertamiento fisiológico y la desunión. A causa de que el cerebro en desarrollo organiza e internaliza nueva información en forma de "uso-dependencia," mientras más el niño está en estado de hiperdespertamiento o desunión, más propenso está a padecer de síntomas neurosiquiátricos con posterioridad al trauma. El estado agudo de adaptación puede convertirse en persistente y conducir a rasgos de maladaptación. Se discuten las implicaciones clínicas de esta nueva conceptualización del neurodesarrollo del trauma en la niñez.

抄録：小児期における外傷は、小児の情緒的、行動的、認知的、社会的、身体的機能に深淵な影響を及ぼす。発達上の体験が、成熟した脳の組織・機能上の状態を決定する。外傷的な体験が脳の発達と機能に与える影響を、神経発達の基本原理という脈絡で論じた。外傷に対する適応的な精神・身体的反応としては、生理的過剰覚醒や解離など、いろいろある。発達途上にある脳は、"使用依存的"な形で"情報"を組み立て、内在化するので、外傷の後は、精神科的な症状を起こしやすい。急性の適応的"状態"の持続が、不適応的な"（永続的）特徴"を招くことがある。小児期外傷をめぐる、この新しい神経発達概念の臨床的意味合いを論じた。

Adults interpret the actions, words, and expressions of children through the distorting filter of their own beliefs. In the lives of most infants and children, these common adult misinterpretations are relatively benign. In many cases, however, these misinterpretations can be destructive. The most dramatic example occurs when the impact of traumatic events on infants and young children is minimized. It is an ultimate irony that at the time when the human is most vulnerable to the effects of trauma—during infancy and childhood—adults generally presume the most resilience.

This destructive misperception has permeated the mental health field. In the last 10 years, our society has spent billions of dollars studying and treating adult trauma victims, primarily male combat veterans—this despite the fact that many more females are traumatized by rape in our society than males by combat. In comparison, few resources have been dedicated to research or treatment focusing on childhood trauma, and only a fraction of those on studying or treating the traumatized infant (Perry, 1994a, 1995).

The purpose of this paper is to discuss various aspects of the impact of traumatic experiences on infants and young children focusing specifically on the relationships between neurodevelopment and traumatic experience. The conceptual views articulated in this paper represent an evolving understanding based upon our extensive clinical experience with young children and infants who have been severely traumatized (n = 175). To some extent, these conceptual views are based upon well-established principles of neurodevelopment applied within the context of less clearly delineated ideas (and data) emerging in the field of traumatology. This is intended as only a preliminary perspective to guide future studies in the clinical phenomenology and neurobiology of child maltreatment.

SCOPE OF THE PROBLEM

Millions of children across the world are exposed to traumatic experiences. These may be pervasive and chronic (e.g., course of conduct maltreatment such as incest;

war) or time limited (e.g., natural disaster, drive-by shooting). Conservative estimates of the number of children in the United States exposed to a traumatic event in 1 year exceed 4 million (Perry, 1994a). These experiences—physical or sexual abuse, living in the fallout zone of domestic or community violence, surviving a serious car accident—all have an impact on the child's development (Osofsky, 1995; Pynoos et al., 1987; Taylor, Zuckerman, Harik, & Groves, 1992). Depending on the severity, frequency, nature, and pattern of traumatic events, at least half of all children exposed may be expected to develop significant neuropsychiatric symptomatology (Schwarz & Perry, 1994). Children exposed to sudden, unexpected man-made violence appear to be more vulnerable—making the millions of children growing up with domestic violence or community violence at great risk for profound emotional, behavioral, physiological, cognitive, and social problems.

One of the most studied neuropsychiatric syndromes which develops following trauma is Posttraumatic Stress Disorder (PTSD). The majority of this work has been with adult combat veterans (DaCosta, 1871; Krystal et al., 1989). In the last 5 years, however, childhood PTSD has been widely observed in various populations of traumatized or maltreated children (McFarlane, 1987). Children exposed to trauma may have a range of PTSD symptoms, behavior disorders, anxieties, phobias, and depressive disorders (Schwarz & Perry, 1994). This includes children who were kidnapped (Terr, 1983), witnessed violent crime (Schwarz & Kowalski, 1991), have been abused (Browne & Finkelhor, 1986; Kiser, Heston, & Millsap, 1991), or survived other severe trauma (Kaufman, 1991). Traumatic experiences in childhood increase the risk of developing a variety of neuropsychiatric symptoms in adolescence and adulthood (Davidson & Smith 1990; Famularo, Kinscherff, & Fenton, 1991; Ogata et al., 1990; Teicher, Glod, Surrey, & Swett, 1993).

Trauma is an experience. How is it that this experience can transform a child's world into a terror-filled, confusing miasma that so dramatically alters the child's trajectory into and throughout adult life? Ultimately, it is the human brain that processes and internalizes traumatic (and therapeutic) experiences. It is the brain that mediates all emotional, cognitive, behavioral, social, and physiological functioning. It is the human brain from which the human mind arises and within that mind resides our humanity. Understanding the organization, function, and development of the human brain, and brain-mediated responses to threat, provides the keys to understanding the traumatized child.

THE HUMAN CENTRAL NERVOUS SYSTEM

The human brain is an amazingly complex organ composed of over 100 billion neurons and ten times as many glial cells, all organized into systems designed to *sense, process, store, perceive,* and *act* on information from the external (e.g., visual, tactile, olfactory, auditory) and the internal (e.g., hormonal signals associated with hunger) environment (see Appendix 1, Key Points; Brain Organization and Function). All of these complex systems and activities work together with one overarching purpose—survival (Goldstein, 1995). The major working units of the brain are neurons, and neurons are interconnected into networks, and networks into systems, and systems work together to mediate a set of specific functions (e.g., vision). Different systems in the brain mediate different functions. Systems in the frontal cortex are involved in abstract thought; systems in the brainstem are responsible for regulating heartrate, blood pressure, and arousal states; systems in the limbic areas are responsible for attachment, affect regulation, and aspects of emotion; and systems in the cortex are responsible for abstract cognition and complex language. Each of these systems varies somewhat with regard to function, specific primary neurotransmitter networks, synaptic structure, and regional localization. All of these neural systems, however, function in a similar fashion on the molecular level. They obey similar molecular rules mediating development, changes in response to chemical signals, and storage of information. (See Table 1.) *The single most significant distinguishing feature of all nervous tissue—of neurons—is that they are designed to change in response to external signals. Those molecular changes permit the storage of information by neurons and neural systems.* Indeed it is this capacity which allows the brain to be responsive to the environment (external and internal) to allow survival of the organism.

Table 1
The Acute Response to Threat

Adaptive Response	REST (Adult Male)	VIGILANCE	FREEZE	FLIGHT	FIGHT
Hyperarousal Continuum	REST (Male Child)	VIGILANCE (Crying)	RESISTANCE Freeze	DEFIANCE 'Posturing'	AGGRESSION
Dissociative Continuum	REST (Female Child)	AVOIDANCE (Crying)	COMPLIANCE Freeze	DISSOCIATION 'Numbing'	FAINTING 'Mini-psychosis'
PRIMARY Secondary Brain Areas	NEOCORTEX Subcortex	SUBCORTEX Limbic	LIMBIC Midbrain	MIDBRAIN Brainstem	BRAINSTEM Autonomic
Cognition	ABSTRACT	CONCRETE	'EMOTIONAL'	REACTIVE	REFLEXIVE
Mental State	**CALM**	**AROUSAL**	**ALARM**	**FEAR**	**TERROR**

When threatened, a human will engage specific adaptive mental and physical responses. Increasing threat alters mental state, style of thinking (cognition), and physiology (e.g., increase heart rate, muscle tone, rate of respiration). As the individual moves along the threat continuum—from calm to arousal to alarm, fear, and terror—different areas of the brain control and orchestrate mental and physical functioning. The more threatened the individual, the more "primitive" (or regressed) becomes the style of thinking and behaving. When a traumatized child is in a state of alarm (because they are thinking about the trauma, for example) they will be less capable of concentrating, they will be more anxious and they will pay more attention to "nonverbal" cues such as tone of voice, body posture, and facial expressions. This has important implications for understanding the way the child is processing, learning, and reacting in a given situation. A traumatized child is often, at baseline, in a state of low-level fear—responding by using either a hyperarousal or a dissociative adaptation—the child's emotional, behavioral, and cognitive functioning will reflect this (often regressed) state.

Use-Dependent Neuronal Changes: Learning, Memory, and Sensitization

All experience is filtered by our senses. All sensory signals (e.g., sound, sight, taste, touch), in turn, initiate a cascade of cellular and molecular processes in the brain that alter neuronal neurochemistry, cytoarchitecture, and, ultimately, brain structure and function. This process of creating some internal representation of the external world (i.e., information) depends upon the pattern, intensity, and frequency of neuronal activity produced by *sensing, processing*, and *storing* signals. The more frequently a certain pattern of neural activation occurs, the more indelible the internal representation. Experience thus creates a processing template through which all new input is filtered. The more a neural network is activated, the more there will be use-dependent internalization of new information needed to promote survival (Cragg, 1975).

The most common examples of this use-dependent storage of information are learning and cognitive memory. A related phenomenon is sensitization. A sensitized neural response results from a specific pattern of repetitive neural activation or experience. Sensitization occurs when this pattern of activation results in an altered, more sensitive system. Once sensitized, the same neural activation can be elicited by decreasingly intense external stimuli (Kalivas & Kuffy, 1989; Kleven, Perry, Woolverton, & Seiden, 1990). In a very real sense, traumatized children exhibit profound sensitization of the neural response patterns associated with their traumatic experiences. The result is that full-blown response patterns (e.g., hyperarousal or dissociation) can be elicited by apparently minor stressors.

Sensitization may result when experience activates neurosensory apparatus, altering the pattern and quantity of neurotransmitter release throughout neuronal systems responsible for sensation, perception, and processing of that specific experience. Trauma will produce such a result. Neurotransmitter receptor/effector activation then alters intracellular chemical constituents, including second (e.g., cAMP, phosphatidyl inositol) and third messengers (e.g., calcium). Changes in these messengers alter the micro-environment of the nucleus, inducing alterations in gene transcription and expression of proteins involved in both neuronal structure and functioning. This, in turn, may cause sensitization of neurotransmitter receptor/effectors to similar future neurotransmitter stimulation in all interconnected neural systems (LeDoux, Cicchetti, Xagoraris, & Romanski, 1989; LeDoux, Cicchetti, et al., 1990).

Use-dependent internalization of the fear response—a "state" memory—can be built into a mature brain (e.g., combat-related PTSD). In the *developing* brain, these states organize neural systems, resulting in traits. The human brain exists in its mature form only as a byproduct of genetic potential and environmental history. Experiences, including traumatic, which may cause sensitization or learning in the mature brain will, during development, determine functional capacity of the human brain. In essence, the same unique molecular characteristics of nervous tissue that allow the mature brain to store new information are those responsible for organizing the brain during development (Goelet & Kandel, 1986; Kandel & Schwarz, 1982).

Developmental Experience: Use-Dependent Organization of Neural Systems

In the developing brain, undifferentiated neural systems are critically dependent upon sets of environmental and micro-environmental cues (e.g., neurotransmitters, cellular adhesion molecules, neurohormones, amino acids, ions) to appropriately organize from their undifferentiated, immature forms (Appendix 1, Key Points: Brain Development). Lack (or disruption) of these critical cues can result in abnormal neuronal division, migration, differentiation, synaptogenesis—all of which contribute to malorganization and compromised function in the affected systems (Cragg, 1975; Lauder, 1988; Perry, Wainwright, Won, Hoffman, & Heller, 1990). Two major principles of neurodevelopment related to the timing and nature of these organizing cues are (1) use-dependent development and organization of the brain and (2) critical and sensitive periods.

The brain develops in a sequential and hierarchical fashion—i.e., from less complex (brainstem) to most complex (limbic, cortical areas). These different areas develop, organize, and become fully functional at different times during childhood. At birth, for example, the brainstem areas responsible for regulating cardiovascular and respiratory function must be intact for the infant to survive, and any malfunction is immediately observable. In contrast, the cortical areas responsible for abstract cognition have years before they will be "needed" or fully functional. This means that there are different times during which different areas of the CNS are organizing and, therefore, either require (critical periods) or are most sensitive to (sensitive periods) organizing experiences (and the neurotrophic cues related to these experiences). Disruptions of experience-dependent neurochemical signals during these periods may lead to major abnormalities or deficits in neurodevelopment—some of which may not be reversible (see below). Disruption of critical cues can result from (1) lack of sensory experience during critical periods or, more commonly, (2) atypical or abnormal patterns of neuronal activation due to extremes of experience (e.g., child maltreatment).

The simple and unavoidable result of this sequential neurodevelopment is that the organizing, sensitive brain of an infant or young child is more malleable to experience than a mature brain. Although experience may alter the behavior of an adult, experience literally provides the organizing framework for an infant and child. Because the brain is most plastic (receptive to environmental input) in early childhood, the child is most vulnerable to variance of experience during this time.

Deprivation of critical experiences during development may be the most destructive yet least understood area of child maltreatment. Unlike broken bones, irreversible maldevelopment of brain areas mediating empathy resulting from emotional neglect in infancy and childhood is not readily observable. Ironically, while rarely studied in humans, the neurodevelopmental impact of extremes of sensory deprivation is the subject of hundreds of animal studies. These studies include disruptions of visual stimuli (Coleman & Riesen, 1968), environmental enrichment (Altman & Das, 1964; Cummins & Livesey, 1979), touch (Ebinger, 1974), and other factors (Sapolsky, Krey, & McEwen, 1984; Sapolsky, Uno, Rebert, & Finch, 1990). These studies illustrated that a very narrow window—a critical period—exists during which specific sensory experience was required for optimal organization and development of the part of the brain mediating a specific function. While these phenomena have been examined in great detail for the primary sensory modalities in animals, similar use-dependent neurodevelopment occurs in all parts of the human central nervous system. Abnormal micro-environmental cues and atypical patterns of neural activity during critical and sensitive periods, then, can result in malorganization and compromised function in brain-mediated functions such as humor, empathy, attachment, and affect regulation.

Some of the most powerful clinical examples of this phenomenon are related to lack of attachment experiences early in life. The child who has been emotionally neglected early in life will exhibit profound attachment problems which are extremely insensitive to any replacement experiences later, including therapy. Examples of this include feral children, children in orphanages observed by Spitz and Wolf (1945) and, often, the remorseless, violent child.

While deprivations and lack of specific sensory experiences are common in the maltreated child, the traumatized child experiences developmental insults related to discrete patterns of overactivation of neurochemical cues. Rather than a *deprivation* of sensory stimuli, the traumatized child experiences overactivation of important neural systems during sensitive periods of development.

THE CHILD'S RESPONSE TO THREAT

The human body and human mind have sets of very primitive, deeply ingrained physical and mental responses to threat (Appendix 1: Key Points: The Response to Trauma). These physiological and mental reactions to danger have been best characterized in adult humans or animal models. The most familiar set of responses to threat has been labeled the "fight or flight" reaction. Indeed, despite a great deal of animal and descriptive clinical data in humans illustrating the heterogeneity of the response to stress (Goldstein, 1995; Mason, 1971), an inordinate clinical focus has been placed on the "fight or flight" response—a pattern commonly seen in adult, male mammals (Cannon, 1914; Selye, 1936).

There are, of course, other response-sets to threat. Clearly, infants and children are much less likely to use a classic "fight or flight" response—it is not very practical. At different stages of development, and in the face of different stressors, response patterns will vary. Two major neuronal response patterns important for the traumatized child, the hyperarousal continuum and the dissociative continuum, are described below.

The Hyperarousal Continuum: Defensive and "Fight or Flight" Responses

In the initial stages of threat, an alarm reaction is initiated (Table 1). The alarm reaction is characterized by a large increase in activity of the sympathetic nervous system, resulting in increased heart rate, blood pressure, respiration, a release of stored sugar, an increase in muscle tone, a sense of hypervigilance, and tuning out of all noncritical information. All of these actions prepare the body for defense—to fight with or run away from the perceived or sensed threat. If the threat materializes, a full fight or flight response may be activated.

This complex set of interactive processes includes activation of the centrally controlled peripheral autonomic nervous system, the immune system (Giller, Perry, Southwick, & Mason, 1990), the hypothalamic-pituitary axis with a concomitant peripheral release of adrenocorticotrophic hormone and cortisol (Sapolsky et al., 1984), and other stress-response neural systems in the brain (Krystal et al., 1989; Perry, Southwick, & Giller, 1990). The locus coeruleus (LC) is the key mediator of the classic "fight or flight" response to threat (Altman & Das, 1964; Elam, Svensson, & Thoren, 1984; Korf, 1976; Svensson, 1987). This bilateral grouping of norepinephrine-containing neurons originates in the pons, a more primitive, regulatory part of the brain, and sends diverse axonal projections to virtually all major brain regions, enabling its function as a general regulator of noradrenergic tone and activity (Moore

& Bloom, 1979). The ventral tegmental nucleus (VTN) also plays a role in regulating the sympathetic nuclei in the pons/medulla.

The "sensitized" hyperarousal response. If a child faced with threat responds with a hyperarousal response, there will be a dramatic increase in LC and VTN activity. This increased release of norepinephrine regulates the total body response to the threat. The brain regions involved in the threat-induced hyperarousal response play a critical role in regulating arousal, vigilance, affect, behavioral irritability, locomotion, attention, the response to stress, sleep, and the startle response (Andrade & Aghajanian, 1984; Bhaskaran & Freed, 1988). Initially following the acute fear response, these systems in the brain will be *reactivated* when the child is exposed to a specific reminder of the traumatic event (e.g., gunshots, the presence of a past perpetrator). Furthermore, these parts of the brain may be *reactivated* when the child simply thinks about or dreams about the event. Over time, these specific reminders may generalize (e.g., gunshots to loud noises, a specific perpetrator to any strange male). In other words, despite being distanced from threat and the original trauma, the stress-response apparatus of the child's brain is activated again and again.

This use-dependent activation of these areas leads to sensitization, and sensitization of catecholamine (LC/VTN-amygdaloid) systems leads to a cascade of associated functional changes in brain-related functions (Vantini, Perry, Gucchait, U'Prichard, & Stolk, 1984; Perry, Stolk, Vantini, Gucchait, & U'Prichard, 1983). This sensitization of the brain stem and midbrain neurotransmitter systems also means the other critical physiological, cognitive, emotional, and behavioral functions which are mediated by these systems will become sensitized. As brain areas involved in the acute stress response also mediate a variety of other functions, sensitization of these systems by repetitive re-experiencing of a traumatic event leads to dysregulation of these functions. A traumatized child may, over time, exhibit motor hyperactivity, anxiety, behavioral impulsivity, sleep problems, tachycardia, hypertension, and a variety of neuroendocrine abnormalities (DeBellis et al., 1994; DeBellis, Lefter, Trickett, & Putnam, 1994; Hoffman, DiPiro, Tackett, Arrendale, & Hahn, 1989; Ito et al., 1993; Perry, 1994a; Perry & Pate, 1994).

This also means, of course, that these components of the fear response, themselves, become sensitized. Everyday stressors that previously may not have elicited any response now elicit an exaggerated reactivity—these children are hyperreactive and overly sensitive. This is due to the fact that, simply stated, the child is in a *persisting* fear state (which is now a "trait"). Furthermore, this means that the child will very easily be moved from being mildly anxious to feeling threatened to being terrorized. In the long run, what is observed in these children is a set of *maladaptive* emotional, behavioral, and cognitive problems, which are rooted in the original *adaptive* response to a traumatic event.

Abnormal persistence of the original hyperarousal seen during the trauma can explain some, but not all of the symptoms traumatized children develop. Indeed, this cannot explain the majority of neuropsychiatric problems that result from pervasive trauma in infancy. Why do more maltreated boys than maltreated girls get referred to the mental health system; why do more males exhibit evidence of sensitized hyperarousal systems (motor hyperactivity, behavioral impulsivity, hypervigilance) following trauma; why do more females exhibit evidence of sensitized dissociative systems (avoidant, depressive, dissociative) following trauma? The answers to these questions are likely to be rooted in understanding the other adaptive response patterns seen in the face of trauma—patterns that may be more adaptive for children or females than for adult males.

This total-body, neurophysiological hyperarousal response exists because it promotes survival. Clearly, if you are an adult male human, it is highly adaptive, in the face of threat, to mobilize a total body response to fight or flee. It is not very adaptive, however, if you are a child or even, as humans evolved, a female. It has been our experience that the hyperarousal response—with the primary adaptive pattern being the defenses of "fight or flight"—is not the primary response to threat in young children and infants. Indeed, young children more commonly utilize a combination of adaptive responses which are designed to, in the early stages of threat, bring caretakers to defend them (an initial hyperarousal response). And, if the threat continues, to move through a dissociative continuum, initially becoming immobile (freezing) and compliant, later completely dissociated; finally, in the extreme, fainting. These responses have been best characterized in animals and have been labeled the defeat or giving up response (Miczek, Thompson, & Tornatzky, 1990). In humans, we will call this set of behaviors a "surrender" response.

The Dissociative Continuum: The Freeze or Surrender Responses

Children, of course, are not particularly well equipped to fight or flee. In the initial stages of distress, a young child will use vocalization (i.e., crying) to get a caretaker to know that they are under threat. This is a successful adaptive response if the caretaker comes and either fights for, or flees with, the young threatened child. Crying, therefore, is a developmentally appropriate response to a threat the child is unable to avoid. Unfortunately, crying infrequently will bring an adult to defend a traumatized child. Indeed, for many of the maltreated children we work with, crying for "help" from a potential trauma is doomed to fail—often the parent causes the trauma. In the absence of an appropriate caretaker response to their initial alarm outcry, the child, eventually after many painful disappointments, will abandon this behavior (a defeat or surrender response). In the face of persisting threat and, depending upon the age of the child and the nature of the threat, the child will move along the hyperarousal continuum (the child's version of "fight or flight") or into the dissociative continuum (Figure 1).

Freezing and oppositional-defiant behaviors. A first reaction in the face of continuing threat may be to freeze. The adaptive advantage of this is clear. Freezing allows better sound localization, keener visual observation—an environmental scan for potential threat. In addition, lack of movement is a form of camouflage, reducing the chance of attracting a predator. In the face of escalating threat, increasing anxiety and decreasing cognitive processing, the freeze response can confer adaptive advantage by allowing one to "organize" and "figure out" how to respond.

Children who have been traumatized and have developed a "sensitized" hyperarousal or "sensitized" dissociative pattern will often use this freezing mechanism when they feel anxious. This is often labeled oppositional-defiant behavior. The child will feel anxious due to an evocative stimulus to which their sensitized neural systems are reacting (e.g., a family visit). They are often not aware of the evocative nature of a given

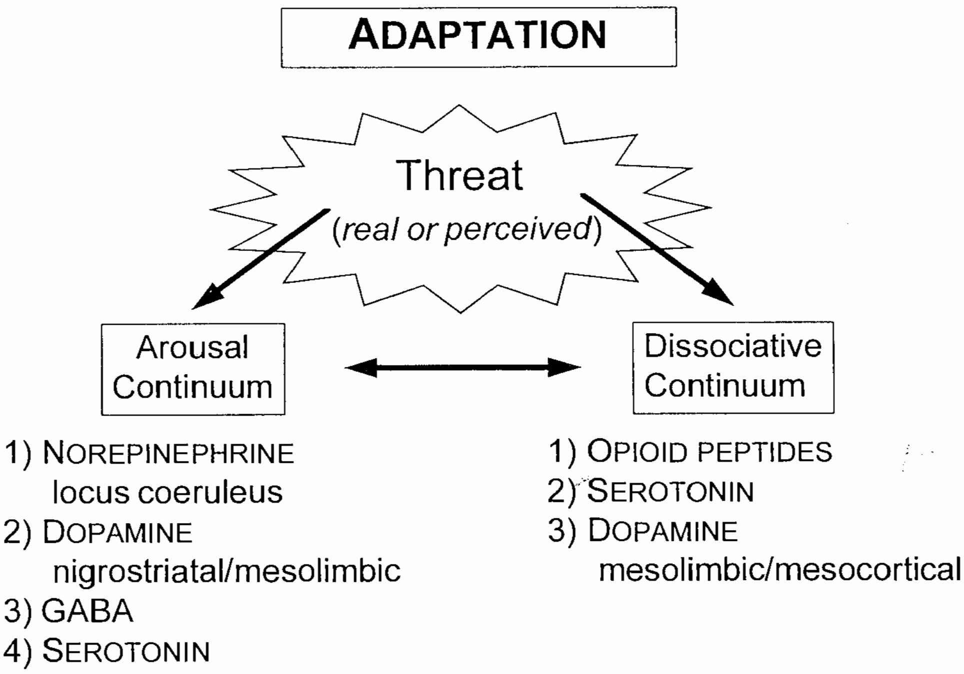

FIG. 1. Patterns of Response to Threat. Two of the major response sets to threat are hyperarousal, leading to "fight or flight" behaviors, and dissociation, leading to "defeat" or "giving up" behaviors. Each pattern has certain adaptive advantages and vulnerabilities. In general, young children (unable to successfully fight or flee) utilize a predominant dissociative response (freeze or surrender) pattern.

event, but what they do experience—deeply—is anxiety. At this point, they tend to feel somewhat out of control and will cognitively (and often, physically) freeze. When adults around them ask them to comply with some directive, they may act as if they haven't heard or they "refuse." This forces the adult—a teacher, a parent, a counselor—to give the child another set of directives. Typically, these directives involve more threat. The adult will say, "If you don't do this, I will . . ." The nonverbal and verbal character of this "threat" makes the child feel more anxious, threatened, and out of control. The more anxious the child feels, the quicker the child will move from anxious to threatened, and from threatened to terrorized. (See Table 1.) If sufficiently terrorized, the "freezing" may escalate into complete dissociation.

Dissociation. Among the constellation of symptoms associated with the trauma response in adults is dissociation. Dissociation is simply disengaging from stimuli in the external world and attending to an "internal" world. Daydreaming, fantasy, depersonalization, derealization, and fugue states are all examples of dissociation (Putnam, 1991). There are gradations of dissociation—from simple daydreaming to profound torture-induced loss of conciousness. Common examples of dissociation in the face of threat have been described following combat. A soldier in the midst of a fire fight may be able to engage in combat, and only after the event is over will he feel his heart racing and look down and see the wound in his leg. Soldiers often utilize an automated, automatic, detached response set. It is during those moments, literally minutes of combat, that the soldier will tell you that there was sound going on all around him but it seemed distant; the event took place as if on a video screen. It is this very ability to dissociate (and utilize a previously internalized set of cognitive and behavioral responses, drilled into them) that can keep soldiers alive.

The capacity to dissociate in the midst of terror appears to be a differentially available adaptive response. Some people dissociate early in the arousal continuum—some people dissociate only in the state of complete terror. Viewed dispassionately, because of the diminished cognitive capacity of an adult in the full-blown fight or flight response, there is great teleological logic in a partial dissociative response (it is what allows the soldier to fight without panic).

It has been our experience with infants and young children that the behaviors exhibited in the acute and post-acute trauma include numbing, compliance, avoidance, and restricted affect, all consistent with a primary dissociative response pattern. Traumatized children use a variety of dissociative techniques. Children report going to a "different place," assuming persona of heroes or animals, a sense of "watching a movie that I was in" or "just floating"—classic depersonalization and derealization responses. Observers will report these children as numb, robotic, nonreactive, "day dreaming," "acting like he was not there," "staring off into space with a glazed look." If immobilization, inescapability, or pain are involved, the dissociative responses will become more predominant.

Neurobiology of the dissociative continuum. The neurobiology of the hyperarousal response involves the catecholamines originating in the brainstem (Murberg, McFall, & Veith, 1990). The neurobiology of the dissociative continuum is different. In animals, the "defeat" response has a distinct neurobiology that appears to match the neurobiology and phenomenology of dissociation (Heinsbroek, van Haaren, Feenstra, Boon, & van de Poll, 1991; Henry, Stephens, & Ely, 1986; Miczek et al., 1990).

As with the hyperarousal/fight or flight response, dissociation involves brainstem-mediated CNS activation, which results in increases in circulating epinephrine and associated stress steroids (Glavin, 1985; Henry et al., 1993; Herman et al., 1982). A major CNS difference, however, is that, in dissociation, vagal tone increases dramatically, decreasing blood pressure and heart rate (occasionally resulting in fainting) despite increases in circulating epinephrine. In addition, there appears to be an increased relative importance of dopaminergic systems, primarily mesolimbic and mesocortical (Abercrombie, Keefe, DiFrischia, & Zigmond, 1989; Kalivas, 1985; Kalivas, Duffy, Dilts, & Abhold, 1988; Kalivas, Richardson-Carlson, & Van Orden, 1986). These dopaminergic systems are intimately involved in the reward systems, affect modulation (e.g., cocaine-induced euphoria), and, in some cases, are co-localized with endogenous opioids mediating pain and other sensory processing. These opioid systems are clearly involved in altering perception of painful stimuli and sense of time, place, and reality. Indeed, most opiate agonists can induce dissociative responses. Of primary importance in mediating the freeze or surrender dissociative response are these endogenous opioid systems (Abercrombie & Jacobs, 1988). There are also a variety of other brainstem, midbrain, and limbic region neurotransmitters that must be involved in this complex set of responses. The important point to keep in mind is that whatever the neurobiology of these dissociative continuum responses, they are distinct from the neurobiology of hyperarousal.

Teleological Significance of the Child's Response to Threat

Why do different individuals use distinct response patterns in the face of threat? Age seems to play a role. Our clinical experience suggests that the younger an individual is, the more likely he or she is to use dissociative adaptations over hyperarousal responses. The nature of the trauma seems to be important to the patttern of adaptation; the more immobile, helpless, and powerless the individual feels, the more likely they are to utilize dissociative responses. When physical injury, pain, or torture (hence, opioid activation) is involved in the traumatic experience, an individual will be more likely to use dissociative responses. Finally, there is a clear sex difference in response patterns; females utilize dissociative adaptations more than males. Some insight into these clinical observations can be found in examining the relationship between these responses and the underlying purpose of all brain-related functions—survival. In order to persist over thousands of generations, each response pattern must have some adaptive advantages.

It is easy to see the adaptive advantage conferred by the aggressively defensive hyperarousal/fight or flight response in adult males. One can only imagine what would have happened to the human species in the face of threat if adult males always dissociated in the face of threat. A group of numb, passive, and immobile humans would be easy prey for natural predators.

Humans evolved over the last 250,000 years in the presence of two major predators: large cats (e.g., tigers, panthers) and, the most dangerous predators, other hominids, including humans. (See Leakey, 1994.) To the cats, all humans (males, females, and children) were roughly equivalent prey, with some preferences for the small, slow, and weak. To other hominids, however, there was a dramatic difference between males, females, and young children. As described extensively in anthropological literature, it was likely a common practice for clans of hominids to raid a competing clan's camp, drive away or kill the males and take the females and young children as property (not unlike the recent history of Western "civilization").

It promoted survival of the species if young children and females survived these raids. It was more adaptive for children to dissociate and surrender than to be hyperaroused and try a fight or flight response. In the face of threat, it was self-protective to become numb, nonhysterical, compliant, obedient, and not combative. Running would result in isolation and sure death. Fighting would be futile.

The same is likely true for adult females. One need not imagine long the response of a violent human male when faced with one female who will willingly comply with the commands to move to his camp and with another who is screaming, yelling, hitting, fighting, and trying to run away. Hyperarousal (fighting or fleeing) would clearly reduce the "property" value of a female, reducing the probability that her genes would be passed to another generation. Both the hyperarousal and the dissociative continuum were selected as adaptive advantages through thousands of generations of clan/tribal intraspecies warfare.

As the human animal matures and grows more capable of fleeing and fighting, the predominance of the dissociative adaptation appears to diminish. It continues to be an extremely important adaptive response in the face of threat, however, in large part because dissociation allows one to maintain or even diminish the internal state of physiological hyperarousal, thereby allowing cognition and problem solving at a higher level of capability than would be possible in a state of absolute terror.

Although there are undoubtedly many other possible reasons for the evolution of dissociation and hyperarousal response, there are clear sex and age differences in predominant adaptive style. This is obvious when examining epidemiological data related to the incidence of neuropsychiatric disorders in male compared to female children. The three-to-one (male to female) ratio of childhood neuropsychiatric problems disappears in adolescence and, suddenly, in early adulthood shifts to become two to one (female to male). In childhood more boys meet diagnostic criteria for externalizing disorders such as ADHD, conduct disorder, and oppositional-defiant disorder whereas more girls have a higher incidence of internalizing disorders such as depressive, anxiety, or dissociative disorders.

The vast majority of young children from backgrounds of abuse and neglect and other trauma who present to the mental health system with symptoms of aggression, inattentiveness, and noncompliance are male. They typically are diagnosed with attention deficit hyperactivity disorder (ADHD). One wonders what happens to all the young girls who have been similarly traumatized. Children present to the mental health system because some adults in their world have been upset by their symptoms (which have almost always been caused by other adults). A compliant, dissociative, depressed young girl will generally *not* be brought to the attention of the mental health system, while her combative, verbally abusive, and behaviorally impulsive hyperaroused sibling (coming from the exact same abusive setting) will be. The potential homicide threatens; the potential suicide inconveniences.

Use-Dependent Internalization of Primary Adaptive Response Patterns

Because the brain changes in a use-dependent fashion and *organizes* during development in response to experience, the specific pattern of neuronal activation associated with the acute responses to trauma are those which are likely to be internalized. The specific symptoms and traits that develop following trauma are related to the individual's pattern of response present in the acute situation. If, in the midst of a traumatic experience, the child dissociates, and stays in a dissociative state for a long period of time (e.g., by re-exposure to evocative stimuli), the child will internalize a sensitized neurobiology related to dissociation, predisposing to the development of dissociative disorders. Conversely, if a child utilizes a predominant hyperarousal response which persists, the child may develop persisting hyperarousal symptoms (Figure 2).

We have followed approximately 50 young children in the acute posttraumatic period. There is a clear relationship between the type of adaptive response utilized in the acute situation and the symptoms that persist at 6 months (see Figure 2; Perry, 1994b, 1995). In our studies utilizing heart rate as a noninvasive indicator of physiological hyperarousal, we have seen that as a child begins to dissociate, his or her heart rate plateaus and in many cases drops. As the dissociating child decreases his or her focus on external threatening cues and increasingly attends to internal cues (e.g., their special place), they feel less threatened and effectively alter the neurobiological pattern

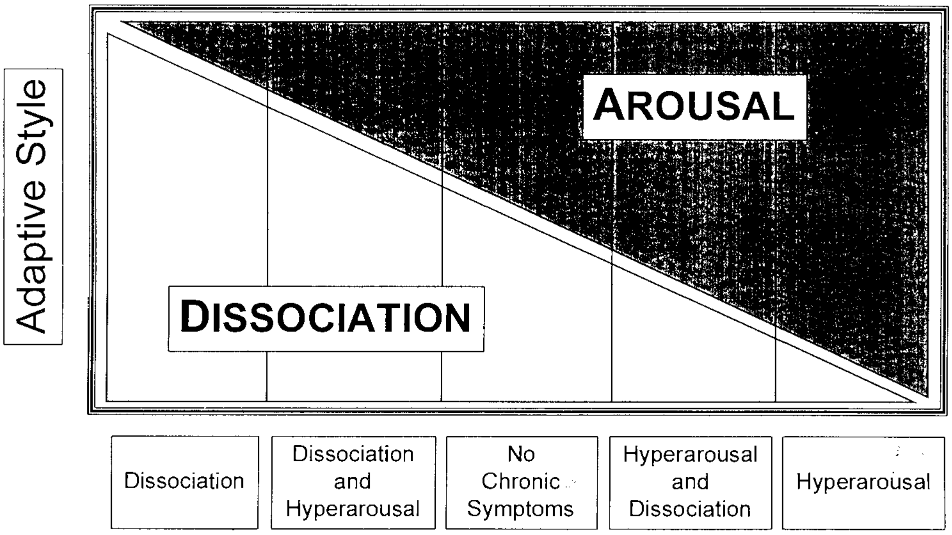

FIG. 2. Adaptive Style and the Development of Neuropsychiatric Symptoms. Use-dependent internalization of symptoms depends upon the predominant pattern of adaptation *during the trauma and immediate postacute period.* Prolonged time periods in a state of dissociation result in the development of dissociative symptoms over time (left box), prolonged periods in a state of hyperarousal result in the development of hyperarousal symptoms (right box). Admixtures of adaptive style result in admixtures of symptoms. The capacity to use moderate levels of both hyperarousal and dissociation results in less time in either state (hyperarousal or dissociation) for prolonged periods of time—decreasing the probability of persisting symptoms related to either state (middle box).

of response to threat, moving along the dissociative continuum from freezing to surrender. This is in sharp contrast to children using a predominant hyperarousal response. These children's heart rates are elevated at baseline and are extremely reactive, dramatically increasing in the face of emotionally laden cognitive or physical cues (Perry 1994b, 1995). As these children move along the hyperarousal continuum, from alarm-vigilance to fear and terror, they continue to use the neurobiological pattern of the well-described "fight or flight" response.

Because the neurobiology and response patterns of dissociation are distinct from those associated with the hyperarousal continuum, one would expect different sets of symptoms to result from the use-dependent internalization of any persisting response to threat. This is indeed the case. The *Diagnostic and Statistical Manual of Mental Disorders,* Fourth Edition (DSM-IV; American Psychiatric Association, 1994) labels routinely applied to the population of severely maltreated children with whom we work vary dramatically. Clearly the DSM-IV does not have adequate descriptive categories for the majority of trauma-related neuropsychiatric syndromes observed in children, especially from deliberately inflicted trauma. Only 70% of our severely traumatized children (all ages) with dramatic symptoms of physiological hyperarousal (n = 120; males/females: 4:1) meet diagnostic criteria for PTSD (Perry, 1995). Furthermore, in our experience, females have many more affective (dysthymia, major depression), dissociative (65% with Child Dissociative Checklist scores over cutoff), and borderline personality features than males with similar severe trauma histories. The majority of all children in our experience who meet criteria for PTSD utilize a combination of persisting, adaptive responses present in the original trauma, involving an admixture of dissociative and hyperarousal responses. These diagnostic and phenomenological complications have hindered research and clinical practice with traumatized children (Scheeringa, Zeanah, Drell, & Larrieu, 1995; Terr, 1991).

CLINICAL IMPLICATIONS

There are a number of clear implications for a neurodevelopmental approach to the maltreated child (Appendix I: Key Points: Clinical Work with Maltreated Infants). The first relates to the misunderstanding of *resilience*. We often hear "Children are resilient," or "They'll get over it, they didn't even known what was happening." It is not uncommon for adults to relate the traumatic events to clinicians in the presence of the child as if they were invisible. Often, recounting the event, the adults will describe how the traumatic event was terrifying for them, but as they describe the child's reactions they frequently misunderstand the child's unattached, nonreactive behaviors as "not being affected" rather than the "surrender" response. This pervasive destructive view of caretaking adults in a young child's life exacerbates the potential negative impact of trauma. Of course, children "get over it"—they have no choice. Children are not resilient, children are malleable. In the process of "getting over it," elements of their true emotional, behavioral, cognitive, and social potential are diminished—some percentage of capacity is lost, a piece of the child is lost forever.

Another major implication of a neurodevelopmental approach is that early intervention, which can ameliorate the intensity and severity of the response to trauma, will decrease the probability of developing, in a use-dependent fashion, sensitized neural systems resulting in either persisting hyperarousal or dissociative symptoms, or both. The more someone is in a dissociative state, the more likely they are to exhibit a dissociative symptomatology. The more they are in a fear state, the more likely they are to carry around persistent symptoms of hyperarousal.

The intensity and duration of response to trauma in children is dependent on a wide variety of factors. One of the most important appears to be the availability of a healthy and responsive caretaker to provide some support and nurturance for the child following the trauma. The presence of a healthy caretaker can diminish dramatically the alarm response or the dissociative response in the young child. Conversely, if the adult is impacted in a similar fashion by the trauma, that will have a significant complicating impact on the child. Indeed, we have worked with a number of very young children and infants who, in acute traumatic experience (e.g., car accident), processed the experience very well. Primary caretakers who were with the children were significantly traumatized by the experience, however. Through their persisting anxiety and inability to contain their persisting hyperarousal symptoms, the primary caretakers build into their children a mirroring hyperarousal fear response—a form of vicarious traumatization. And, if the "caretaker" is the source of the trauma, the child's emotional survival depends on a zone of safety that includes new, true caretakers.

Different events at different times in the life of an individual are likely to result in a different combination of adaptive responses. An infant, a child, and an adolescent experience the same event in different ways. What may be extremely traumatic for an adolescent may be a nonevent for an infant (e.g., the threat of an armed robbery). Conversely, there are many experiences that are likely to be traumatic for infants which are minimally threatening for adolescents (e.g., separation from primary caretakers). Factors related to the individual's specific response to a given trauma include (1) premorbid functioning and history, specifically history of previous stressors; (2) age—the neurobiological response patterns appear to change with age; (3) specific cognitive meaning of an event for an individual; (4) the specific nature of the trauma; and (5) presence of exacerbating (loss of caretaker) or attenuating factors (e.g., early intervention).

CONCLUSIONS

Children and infants use a variety of adaptive response patterns in the face of threat, and, in a use-dependent fashion, internalize aspects of these responses, organizing the developing brain. There are a variety of neuropsychiatric symptoms that result when these patterns of neural activation persist. This has implications for research, clinical assessment, intervention, and prevention.

More important, however, is that understanding the impact of experience on the developing child by using a neurodevelopmental conceptualization offers certain directions for our culture (Perry, 1996). Profound sociocultural and public policy implications arise from understanding the critical role of early experience in determining the functional capacity of the mature adult—and therefore our society. Persistence of the destructive myth that "children are resilient" will prevent millions of children, and our society, from meeting their true potential. Persistence of the pervasive maltreatment of children in the face of decreasing global and national resources will lead, inevitably, to sociocultural devolution.

It need not be so.

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APPENDIX 1

KEY POINTS: BRAIN ORGANIZATION AND FUNCTION

- The brain is not a "single" system. It is many interacting and interconnected systems organized in a specific hierarchy—with the most complex (cortex) on the top and the least complex (brainstem) on the bottom.
- Different parts of the brain—different "systems" in the brain—mediate different functions (e.g., the cortex mediates thinking, the brainstem/midbrain mediate state of arousal).
- All systems in the brain are composed of networks of nerve cells (neurons). These neurons are continuously "changing" (in chemical and structural ways) in response to "signals" from other parts of the brain, the body, or the environment (e.g., light, sound, taste, smell).
- The "changes" in neurons allow the storage of "information." This storage of information is the basis for "memory"—memory of all types—motor, sensory, cognitive, and affective.
- Different parts of the brain—which mediate different functions—store information (memory) that is specific to the function of that part of the brain. This allows for different types of "memory"—for example, cognitive (names, phone numbers), motor (typing, riding a bicycle), "affect" (nostalgia).
- The brain stores information in a use-dependent fashion. The more a neurobiological system is "activated" the more that state (and functions associated with that state) will be "built" in—for example, practicing the piano, "memorizing" a poem, or staying in a state of fear.
- In different "states" of arousal (e.g., calm, fear, sleep), different neural systems are activated. Because the brain stores information in a use-dependent fashion, the information "stored" (i.e., the memories) in any given situation depends upon the state of arousal (i.e., the neural systems that are activated). One example of this is "state-dependent" learning—another is the hyperarousal symptoms seen in post-traumatic stress disorder.

KEY POINTS: BRAIN DEVELOPMENT

- The brain develops in a predictable fashion—from most primitive to most complex. Ontogeny recapitulates phylogeny.
- Normal development of neuronal systems (and functions they mediate) requires specific patterns of activity—specific "signals"—at specific times during development.
- These *critical periods* are windows of vulnerability during which the organizing systems are most sensitive to environmental input—including traumatic experience.
- Because the different systems in the brain develop (or mature) at different times in the life of a child, there are different critical periods for different functions (e.g., regulation of anxiety, mood, abstract thought).
- Because these brain systems develop in a sequential fashion, from brainstem to cortex, optimal development of more complex systems (e.g., the cortex) requires healthy development of less complex systems (e.g., the brainstem and midbrain).
- Therefore, if the state-regulating parts of the brain (brainstem and midbrain) develop in a less than optimal fashion (e.g., following excessive traumatic experience) this will impact development of all other regions of the brain.
- The brain remains sensitive (plastic) to experience throughout life—but different parts of the brain are most plastic (cortex) and others are relatively implastic (brainstem).
- EXPERIENCE CAN CHANGE THE MATURE BRAIN—BUT EXPERIENCE DURING THE CRITICAL PERIODS OF EARLY CHILDHOOD *ORGANIZES* BRAIN SYSTEMS!
- Trauma during infancy and childhood, then, has the potential effect of influencing the permanent organization—and all future functional capabilities—of the child.

KEY POINTS: THE RESPONSE TO TRAUMA

- The brain mediates threat with a set of predictable neurobiological, neuroendocrine, and neuropsychological responses.
- These responses may include different "survival" strategies—ranging from fighting or fleeing to "giving up" or a "surrender" reaction.
- There are multiple sets of neurobiological and mental responses to stress. These vary with the nature, intensity and frequency of the event. Different individuals may have differing "response" sets to the same trauma.
- Two primary adaptive response patterns in the face of extreme threat are the hyperarousal continuum (defense—fight or flght) and the dissociation continuum (freeze and surrender response). Each of these response "sets" activates a unique combination of neural "systems."
- These response patterns are somewhat different in infants, children and adults—though they share many similarities. Adult males are more likely to use hyperarousal (fight or flight) response—young children are more likely to use a dissociative pattern (freeze and surrender) response.
- As with all experience—when the brain "activates" the neurophysiological systems associated with alarm or with dissociation, there will be use-dependent neurobiological changes (or in young children, use-dependent *organization*) which reflect this activation.
- These use-dependent changes in the brain development and organization underlie the observed emotional, behavioral, cognitive, social, and physiological alterations following childhood trauma.
- In general, the predominant adaptive style of an individual in the acute traumatic situation will determine which posttraumatic symptoms will develop—hyperarousal or dissociative.

KEY POINTS: CLINICAL WORK WITH MALTREATED INFANTS

- Anything that can decrease the intensity and duration of the acute response (alarm or dissociative) will decrease the probability of persisting neuropsychiatric symptoms.
- In general, structure, predictability, and nurturance are key elements to a successful early intervention with a traumatized infant.
- The primary source of these key elements is the primary caretaker. Therefore, it is critical to help the caretakers understand as much about posttraumatic responses as possible.
- If the primary caretakers were impacted by the same trauma, it is imperative that they get treatment which complements the work with the child.
- Early assessment and intervention can be prophylactic—helping prevent a prolonged acute neurophysiological, neuroendocrine, and neuropsychological trauma response.