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Review

Primitive mechanisms of trauma response: An evolutionary perspective on trauma-related disorders

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ABSTRACT

The symptoms we identify and the behaviors we recognize as defenses define which symptoms we see as trauma-related. Early conceptions of trauma-related disorders focused on physical signs of distress while current ones emphasize mental symptoms, but traumatizing experiences evoke psychobiological reactions. An evolutionary perspective presumes that psychophysical reactions to traumatizing events evolved to ensure survival. This theoretical review examines several primitive mechanisms (e.g., sensitization and dissolution) associated with responses to diverse stressors, from danger to life-threat. Some rapidly acquired symptoms form without conscious awareness because severe stresses can dysregulate mental and physical components within systems ensuring survival. Varied defensive options engage specialized and enduring psychophysical reactions; this allows for more adaptive responses to diverse threats. Thus, parasympathetically mediated defense states such as freeze or collapse increase trauma-related symptom variability. Comorbidity and symptom variability confuse those expecting mental rather than psychophysical responses to trauma, and active (sympathetically mediated flight and fight) rather than immobility defenses. Healthcare implications for stress research, clinical practice and diagnostic nosology stem from the broader evolutionary view.

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1. Introduction

> Nothing makes sense in biology except in the light of evolution (Dobzhansky, 1964, p. 449)

The history of trauma-related diagnoses shows that how we classify Posttraumatic Stress Disorder (PTSD) depends on the symptoms we see and the behaviors we recognize as defenses. In the US Civil War, the most closely corresponding diagnosis was irritable heart (Da Costa, 1871), colloquially called soldier's heart (Mackenzie, 1920). During World War I, similar symptoms were diagnosed as shell shock or the effort syndrome (Lewis, 1940). With World War II came the diagnosis of traumatic neurosis (Kardiner, 1940). Though the symptoms seen were relatively stable over time, serial diagnoses emphasized differing features. The early medical diagnoses cued in on somatic complaints, such as exertion, infection, and cardiac or thyroid issues. Yet medical explanations of these signs failed to eradicate soldier's heart. As Wilson (1916, p. 120) lamented, "The theorists ... are bankrupt; the disease remains". When cardiac symptoms came to be seen as signs of anxiety after World War I, the physical symptoms associated with soldier's heart were no longer treated as medical problems (Cohn, 1919).

The term PTSD first appeared as an anxiety disorder in the third edition of the American Psychiatric Association's *Diagnostic and Statistical Manual of Mental Disorders* (DSM) (APA, 1980). We continued to group PTSD among the anxiety disorders until the DSM-5 (APA, 2013). The diagnostic criteria for PTSD still emphasize sympathetically mediated behavioral responses to traumatic events (APA, 2000, 2013). How we see or understand trauma-related disorders has research and clinical implications because our perceptions guide diagnosis, research and treatment. For example, only individuals who complain of mental symptoms are diagnosed with PTSD, not those displaying the cardiac signs that would historically have been used to diagnose irritable heart. Some researchers contend that our culture influences trauma responses, while others stress that our biological survival informs these responses. Both may be right; but conflicting perspectives such as these could give rise to differing perceptions of trauma, some of which fail to consider exactly what occurs during a traumatizing experience. The PTSD diagnosis highlights reliably observable behaviors. It has provided a focal point for research and has increased the visibility of trauma-related issues. However, our prevailing notions about trauma responses cannot explain the variability that is seen to surround this disorder.

This variability is manifest in two forms: as comorbidity across disorders and as varied symptoms that can change over time. The PTSD diagnosis is highly comorbid with other mental health diagnoses (e.g., anxiety, bipolar disorder, depression, dissociative disorders, personality disorders, schizophrenia, and substance abuse; Courtois and Gold, 2009; Kessler et al., 2005; Moskowitz et al., 2008). Traumatic events are also surprisingly comorbid with physical illnesses (Boscarino, 2008; Felitti et al., 1998), with chronic pain (Lyon et al., 2011), and with some medically unexplained symptoms (Brown, 2007). In addition, traumatized individuals who receive a diagnosis of PTSD often display widely different symptoms, some of which seem unrelated to sympathetic activity (Lanius et al., 2003; Orr et al., 2004). Symptoms also vary within people over time (Mason et al., 2002; Reinders et al., 2006).

The confusion around both forms of variability has historical roots. Immunology and neuroendocrinology became distinct academic disciplines because researchers discovered immune and neuroendocrine systems separately. We expect that cognitive and noncognitive threats will elicit separate central, endocrine, or immune responses. Ader (1981) coined psychoneuroimmunology (PNI) as a term in the year after publication of the DSM-III; still, the bidirectional communication among psychobiological elements that is inherent in PNI has never informed the criteria for PTSD. Comorbid physical disorders surprise us because they violate a presumed independence of distinct reactions to different threats. Yet the fact that comorbid disorders exist shows that our reactions to cognitive and noncognitive threats are not orthogonal.

Two implicit premises in the prevailing cognitive perspective impede a full understanding of trauma-related symptoms. One is that mental disorders merit mental explanations. Although mental explanations fruitfully address many affective disorders, they do not always fully resolve trauma-related disorders. Generalizing this premise to trauma-related disorders hinders our understanding of the comorbidities observed between traumatic-stress and physical diseases. The second premise is that only active defenses count as responses to trauma. Cannon (1932) contended that we respond to stress with sympathetically mediated actions (i.e., fight or flight). Clinicians and researchers followed his lead by categorizing PTSD as an anxiety disorder (APA, 1980, 2000; Gray and McNaughton, 2000). Yet parasympathetically mediated defenses generate symptoms as well; the variability accompanying these symptoms baffles us because we do not see immobility responses as defenses, if we notice them at all. These premises fail to account for the primitive mechanisms seen in trauma-related defensive responses.

In contrast, an evolutionary perspective sees both traumatizing experiences and defensive responses through the longer lens of biological survival. Humans inherited the same defensive options that animals use to survive threats such as predation. Bite wounds carry a high incidence of pain and infection. Predation and associated emergencies, such as infection, require rapid and effective reactions that take priority over ongoing behaviors. The ability to coordinate across discrete survival systems should enhance the responsiveness and effectiveness of behavioral, immune, and neuroendocrine defenses. Given a shared goal of protecting the host, it would certainly be adaptive for mammalian behavioral defenses to tap into reciprocal communication with the central nervous system (CNS) and central autonomic network (Maier, 2003). Indeed, this would support immunological memory and learning motivated by survival demands. Survival-related learning seems to exploit internal signals of threat, possibly co-opted from older immunologic responses to antigens (Ottaviani and Franceschi, 1996). Our brain coordinates the neural and physical elements of survival systems, but severe stress disrupts this coordination. Disruptions in the bidirectional dialogs between the CNS and peripheral signals may give rise to trauma-related symptoms. Persisting dysregulation of primitive mechanisms prolongs symptoms after a danger has passed. It follows that trauma-related symptoms are psychobiological, and inherently so. They stem from disruptions in primitive

mechanisms, including elements within survival-related systems. In this respect, the symptoms evoked by traumatic-stress differ from behavioral symptoms that do not arise from stress, even when they appear similar.

This theoretical review focuses on primitive mechanisms associated with our reactions to diverse threats to survival. Primitive mechanisms contribute to the comorbidity observed among mental and physical disorders. Peripherally signaled autonomic participation in the panoply of defensive responses to stress or trauma is explored as another type of primitive mechanism. Varied defense states engender varied symptoms that differ both between people and within individuals over time. Thus, primitive reactions to traumatizing experiences potentially lead to symptom variability as well as to comorbidity. By taking a broader evolutionary view, we could advance the nosology of stress-related disorders. Nonlinear methods offer promising concepts and analytical tools for understanding the observed variability and will be discussed throughout the article. It is tough to gauge comorbidity and symptom variability using the prevailing perspective. I discuss why in Sections 3 and 4.

2. An evolutionary take on trauma and survival

An early view proposed that the hierarchical organization of the mammalian brain evolved to allow newer and more differentiated neural circuits to regulate the reflexes of ancient regions (MacLean, 1990). One current view suggests that abstract human cognitive abilities emerge out of negotiations around pre-existing internal (visceral) and external (somatic) constraints imposed by the brain's location within the physical body (Tucker, 2007). Our brains differ from other mammals more in these newer cortical areas, and less in the older parts. If survival is threatened, older brain regions react to external as well as internal threats. Despite clear species differences, the basic defensive options are highly conserved across mammals. Indeed, birds (Ramirez and Delius, 1979), fish (Smith, 1992), and insects (Adamo, 2010) show similar responses. It is difficult to imagine anything more harshly selected through natural selection than the adaptations of predators and prey (Barrett, 2005). Reactions to infection preceded and likely evolved into behavioral responses to predators (Ottaviani and Franceschi, 1996). Hughlings Jackson's (1884/1958) concept of *dissolution* pertains here. When severe stress overwhelms our cortical functions, newly unregulated primitive brain areas are freed to respond autonomously. The mental, behavioral and physiological reactions to stress that originate in these ancient responses integrate poorly with our conscious experience. Some defensive behaviors are unconscious (Bargh and Morsella, 2008) and coordinated outside of human conscious awareness (Mobbs et al., 2009; Price, 2005). Organisms respond to valid danger signals regardless of their origin. This is because signals from the periphery convey contextual information that aids central processing. For instance, Von Frisch's *Schreckstoff*, a pheromone released from the skin, denotes injury when a schooling fish is bitten (Smith, 1992). Schreckstoff signals conspecifics to move away and predators to feed. Simple mechanisms analogous to Schreckstoff may occur in mammals, including humans, as well.

2.1. Primitive mechanisms

Sensitization and kindling are two examples of primitive mechanisms. Sensitization means a progressive amplification of neural responses to repeated stimuli. Kindling refers to excitable sensitized reactions to repeated stimuli (e.g., as in seizures). Charney et al. (1993) proposed that sensitization, fear conditioning, and failure of extinction are psychobiological mechanisms involved in PTSD. Post and colleagues discussed behavioral sensitization and kindling as linked to PTSD symptoms (Post et al., 1995) and the recurrence of depressive episodes (Post, 2007). Charney et al. saw that sensitization could explain the heightened responsiveness of PTSD patients to repeated stressors, and that fear conditioning might explain the re-experiencing symptoms and compensatory avoidance or numbing. They proposed that failures of extinction could explain the persistence of traumatic memories. Perhaps these and other primitive mechanisms can expand our ability to describe still other unexplained trauma-related symptoms. An evolutionary perspective provides a path to find and explore such mechanisms.

In MacLean's (1990) triune brain, cortical circuits monitor and regulate less differentiated reptilian and limbic areas. In normal learning, for example, processes of sensitization and habituation work together to spot relevant and ignore irrelevant stimuli. However, sensitization and habituation are associated with granular or pyramidal neural cells in human dorsal and ventral corticolimbic networks that can become selectively active in contexts that are safe or threatening (Tucker and Luu, 2012). The cortical parts of these two networks lie respectively in the left and right hemispheres. Pribram (2013) notes that left hemisphere narrative processes become experienced in the third person, while right hemisphere processes are experienced in a first-person mode. Our brains reuse existing circuits for new purposes; many human emotional or cognitive functions are also integrated across the vertical hierarchical levels. Physical pain and emotional rejection both elicit responses in similar brain areas (Kross et al., 2011). Human empathic concern for others may have evolved out of a capacity to tolerate psychological pain (Tucker et al., 2005). Traumatizing experiences disrupt the function of, and coordination between, the dual corticolimbic networks. This impairs the effective coordination of survival elements. As psychobiological reactions give rise to symptoms that are sensitive to stress, our primitive mechanisms contribute to trauma-related disorders in baffling ways. Some PTSD symptoms reflect a sensitization bias that comes from the human ventral corticolimbic network. Appearing suddenly, these symptoms are highly specific, persistent, and resist habituation.

The bidirectional communication that is central to psychoneuroimmunology shows how primitive mechanisms can cross the artificial mental boundaries that divide physical and mental disorders. Primitive mechanisms make little sense outside of this conceptual frame. They are easily overlooked when we forget that peripheral signals can alter central activity. Survival learning might engender physical disorders, while mental or emotional issues arise from psychobiological processes. For example, peptides and other substances serve evolutionarily conserved survival functions. Substance P and its NK1 receptor (Rosenkranz, 2007), ubiquitous throughout the body, are involved in sensitization and share features with many common denominators of stress responses in bacteria (Lyon et al., 2011). In PTSD patients, substance P responds acutely to psychological stressors. It is elevated in disorders sensitive to stress, such as sleep disturbance, depression, and several comorbidities of physical pain (Geracioti et al., 2006; Lyon et al., 2011). Stam (2007a,b) reviewed neuropeptide Y and other CNS substrates implicated with stress sensitization and PTSD in humans and animals. Widespread pain is another expression of a conserved system designed to defend or repair the organism following threats to homeostasis (Lyon et al., 2011). Chronic pain is also associated with sensitization. Multiple sensitizing signals in the periphery and within the CNS actively generate pain (Woolf and Salter, 2000). Indeed, neuronal plasticity to detect and remember stimuli may have evolved to avoid pain (Lyon et al., 2011; Woolf and Salter, 2000). Primitive mechanisms, including basic processes of learning, help explain how severe stress could engender physical disorders. These processes operate outside our awareness, so they might well escape our notice.

Another example is in order. In numerous publications between 1955 and 1996, Garcia and colleagues described examples of

primitive learning in survival conditions. Rats normally fed water received saccharine and were promptly made ill with radiation. In several studies, these subjects refused saccharine after they recovered. Taste aversions occurred even when the rats were anesthetized immediately after drinking the saccharine and were kept unconscious all the way through the radiation sickness (Bermudez-Rattoni et al., 1988). These highly specific and rapidly acquired aversions are consistent with sensitization, but they contravene the normal rules of learning. They are difficult to explain in terms of operant or classical conditioning (Garcia et al., 1989). As long as specific criteria are met, Garcia's surprising and robust findings hold true across various anesthetics and mammalian species, including humans (Garcia, 1990). They imply that peripheral and central elements work together during survival situations. More broadly, and consistent with these results, interoceptive conditioning demonstrates that the viscera are able to initiate and convey some acquired conditioned information (Razran, 1961).

An evolutionary perspective acknowledges bidirectional dialog in the service of survival. It sees primitive mechanisms as a fruitful way to look at PTSD symptoms. Some primitive mechanisms require bidirectional dialog between peripheral and central elements. They suffer from stress-related communication breakdowns. Others (e.g., dissolution) cause or arise from such failures. The fact that sensitization is seen in chronic pain implies that shared pathways connect comorbid disorders. This, in turn, suggests that stress-related physical disorders contain both biological and psychological elements. Primitive mechanisms are broadly influential because they are basic and critical. Sensitization processes appear to be involved in the taste aversions of Garcia's rats and in the resistance of symptoms to resolution via cognitive treatment approaches for humans with PTSD. Some survival elements are also highly specific. Garcia's results imply that a specific primitive defense system protects the gut from ingested toxins (Garcia et al., 1985). Section 2.2 describes bidirectional processes in survival systems. Because severe stress impairs effective coordination across their elements (inflammation, sensitization, etc.), I refer to survival systems as entangled.

2.2. Survival systems

Blalock (2005) and Blalock and Smith (2007) described the immune system as a sensory organ that acts as a sixth sense, identifying and communicating information about threats not recognized as dangerous by central or peripheral neural systems. Survival situations involve the immune system, and immune involvement entails other systems. Our psychological responses to stress trigger inflammatory and neuroendocrine alterations that can impair physical health (Kendall-Tackett, 2009). Brain-immune communications arising from either neurons or immune cells use cytokines, neuropeptides, and neurotransmitters as signaling molecules (Blalock and Smith, 2007). The ensuing dialog involves both parasympathetic (Borovikova et al., 2000) and sympathetic (Benarroch, 2009) branches of the autonomic nervous system (ANS). By activating the hypothalamic–pituitary–adrenal (HPA) axis and the sympathetic–adrenal–medullary system (Sternberg, 2006), the brain creates the energy that allows fever to fight infection (Maier, 2003). Non-specific behavioral signs, or *sickness behaviors* (i.e., altered cognition, depressed mood, disturbed sleep, lethargy), promptly reduce competing energy demands in many species (Hart, 1988; Kent et al., 1992). This fits with the idea that survival systems coordinate their actions.

Psychobiological elements are entangled across all severity of stressors. For example, the emotion of disgust actually serves to avoid disease. Stevenson et al. (2012) found that disgust activates immune responses and increases body temperature in men. At a more mundane level, drowsiness follows a heavy meal and fear reduces appetite; this is because the energy required for digestion or fear, respectively, limits our available energy for physical activity and eating. Survival systems coordinate behavioral and physiological elements (i.e., our psychobiological reactions) to best marshal limited metabolic energy in response to diverse threats. Accordingly, there is a dose–response association between psychological stress and various causes of mortality (Russ et al., 2012). The risk of death increases from cardiovascular events and from suicide soon after a person learns they have a deadly cancer (Fang et al., 2012). Recurrent traumatizing experiences during childhood can alter how the growing brain develops (Schore, 2003). The behavioral defense response that we choose alters the way in which stress dysregulates the HPA (Korte et al., 2005). The strength of entangled survival systems lies in their rapid and effective responses. A weakness is that stress-related disruptions pervade inflammatory, neuroendocrine, and behavioral elements. These entanglements could impair the function or coordination of components, eventually disorganizing our defenses.

Infection was a prominent etiological factor in irritable heart (Da Costa, 1871), and occurred in about 80% of the cases with soldier's heart (Mackenzie, 1920). Additionally, it was often seen in soldiers diagnosed with effort syndrome (Lewis, 1940). PTSD patients show autonomic, immune and neuroendocrine alterations (Lewitus and Schwartz, 2009; Pace and Heim, 2011), including epigenetic changes (Uddin et al., 2010) associated with long-term immune function. Enhanced inflammation appears to increase the risk of comorbid somatic diseases in women with PTSD from childhood abuse (Pace et al., 2012). Current long-term psychological stress increases glucocorticoid receptor resistance in humans (Cohen et al., 2012). This impairs the down-regulation of pro-inflammatory cytokines and prolongs our inflammation response (Cohen et al., 2012). The phylogenetically ancient co-occurrence of inflammation and sickness behaviors evolved into psychophysical participation in our trauma responses and trauma-related disorders. Indeed, peripheral and central cytokines mediate mammalian host defenses against infection as they do because the blood–brain barrier emerged during evolution to protect the brain, thereby disrupting communication between phyogenetically older immune cells and preexisting neural control circuits (Maier, 2003). We rarely ask about infection when assessing for PTSD, but perhaps we should.

One more concept needs introducing here. *Immune privilege* limits its damage within the brain from peripheral inflammation. This privilege applies only to the parenchyma; information crosses the blood–brain barrier at the choroid plexus, circumventricular organs, meninges, and ventricles (Galea et al., 2007). Central cytokines, whether sensitized by the stress of infection or from emotional trauma, are responsible for sickness behaviors (Dimsdale and Dantzer, 2007). However, peripheral cytokines induce expression of the same cytokines inside the brain (Dantzer et al., 2008). This allows cellular and molecular images of the peripheral stress or inflammatory responses to form across this barrier (Dantzer et al., 2008). Garcia's anesthetized rats became suddenly averse to saccharine in this way. Radiation poisoning created toxins in their blood that crossed the blood-brain barrier at the area postrema (Garcia, 1990).

From an evolutionary perspective, comorbid nervous and physical disorders occur in a context of incomplete coordination between behavioral and physical defensive elements. Entangled psychobiological elements likely respond to all manner of survival threats: internal or external, infection or predation, and social or nonsocial. Signals from the periphery convey contextual information to the brain when they coincide with traumatizing experiences, and repetition strengthens these associations. Yet stress disrupts primitive mechanisms as it impairs the bidirectional communication within or across elements of survival systems. Brief disruptions

could affect both neural and humoral pathways; prolonged or repeated disruptions set the stage for these components to be dysregulated. Dysregulation contributes to the connection observed between traumatizing experiences and various comorbid physical issues. This is especially clear for disorders sensitive to stress and for chronic conditions associated with inflammation (Rosenkranz, 2007), such as chronic pain (Lampe et al., 2003; Lyon et al., 2011) or heart diseases (Boscarino, 2008). Thus, both mental and physical symptoms invariably characterize all our responses to trauma. This means that disorders sensitive to stress stem from psychobiological reactions, even if the eliciting stressor is purely psychological.

3. Psychobiological reactions create comorbidity

As seen from the cognitive perspective, the brain perceives and responds to traumatizing events; peripheral signals, including somatic sensations such as heart rate, merely reflect the downstream consequences of central decisions. To those who share this prevailing view, it follows that our focus should be on the brain, not on the periphery. Yet de-emphasizing physical symptoms in PTSD undercuts the basis for recognizing comorbidities between traumatizing events and physical disorders. An evolutionary perspective accepts that behavioral responses to cognitive stressors share not just common hormones and receptors, but also ancient origins and primitive functional mechanisms with immunologic responses to antigens (Maier, 2003; Ottaviani and Franceschi, 1996). To fathom comorbidity, we need to employ this broader outlook. The next three sections address the process of comorbidity as seen through an evolutionary lens. I describe relevant bidirectional communications between the brain and the periphery from top-down (Section 3.1) and bottom-up (Section 3.2) perspectives, and then discuss primitive associations that form as survival is threatened in Section 3.3. Survival conditions spawn PTSD. Note that some PTSD symptoms show signs of dysregulation and primitive survival learning.

3.1. The central perspective

A purpose of neural activity in response to stress is to select optimal defenses for survival of the organism. Widely distributed cortical areas select defensive strategies; subcortical areas execute responses (Gray and McNaughton, 2000; Tucker and Luu, 2012). For example, different parts of the midbrain periaqueductal gray (PAG) implement active and immobility defenses (Porges, 2011). Just above the brainstem, the hypothalamus prepares the mammalian body to carry out a selected defensive response via efferent ANS influences on heart rate, blood pressure, and blood distribution (shifts from the gut and toward leg muscles permit faster running). As Garcia's rats demonstrated, sensitivity to peripheral signals of danger can inform both the perception of and reactions to threats. Indeed, phylogenetically newer cortical regions such as the right anterior insula, anterior cingulate, and orbitofrontal cortex integrate afferent interoceptive feelings from the body (e.g., autonomic and visceral sensations) to form a sense of self as well as awareness of emotions and sickness behaviors in humans (Craig, 2002; Critchley, 2005; Dantzer et al., 2008). Exactly how peripheral stress or inflammation affects brain activity is unclear; measuring the signaling pathways inside living brain is difficult (Dantzer et al., 2008). As cortical regulation of peripheral danger signals is impaired by stress, those signals become dysregulated. Over time, the defenses themselves may become disorganized.

An evolutionarily older "fast" neural system and a newer system (LeDoux, 1996), both involving the basolateral amygdala (Amaral, 2003; Davis and Whalen, 2001), respond to danger, threat and uncertainty in mammals including humans. The fast system is quite old. In humans, it initiates unconscious and reflexive defensive responses (Morris et al., 1999). Bypassing the cortex, this older system includes the right amygdala, thalamus, hypothalamus, and PAG, along with sensory organs (LeDoux, 1996). Cortical and hippocampal connections in the newer route allow us to have the experience of fear. Although cortical connections slow response time, they more accurately evaluate sensory information and facilitate voluntary coping (Hariri et al., 2003; LeDoux, 1996). Data from animals corroborate this. Both fast and slow neural systems control cardiovascular responses via the lateral hypothalamus and prefornical region in baboons (Smith et al., 1990). Stimulation of different portions of the PAG elicits active and immobile defense responses in rats and cats (Bandler et al., 2000). Lateral and dorsolateral areas of the PAG are associated with the sympathetic branch of the ANS and with active defenses in rats (Jansen et al., 1995). Thus, the ventrolateral PAG is associated with immobility and the unmyelinated dorsal vagal complex in several mammalian species, including humans (Bandler et al., 2000; Porges, 2011).

LeDoux's two neural systems convey contextual information pervasively to cortical areas. Neocortical differentiation advances from limbic origins. Specifically, two distinct corticolimbic networks arise from limbic and subcortical areas in humans. They are specialized to respond to differing conditions. Tucker and Luu (2012) contrast a dorsal (mediodorsal frontal) network, active during safety and distinguished by impulse and habituation, from a ventral (ventrolateral and orbital frontal) network that accommodates to novelty and survival pressures. The dorsal network lies primarily in our left hemisphere; the ventral network is dominant in our right. These two corticolimbic networks differ in their evolutionary and ontogenetic origins, as well as neural cells and neurotransmitters. They are specialized for distinct learning and motivational styles, as Pribram (2013) also notes. Tucker and Luu report that the dorsal network's pyramidal cells arise limbically from the hippocampus and anterior cingulate, seeing the world you imagine. In contrast, the ventral network's granular cells, based limbically in the extended amygdala and insula, monitor and react to real world constraints, including various threats. Consolidation of memory also differs; consolidation flows mainly to limbic areas in the ventral network, and from limbic areas in the dorsal network. Tucker and Luu suggest that reported characteristics of our stressful memories might stem from the differing memory consolidation processes of the two networks. Whereas the intentional dorsal network handles assimilation learning and spatial or configural memory, chaotic or stressful situations engage the ventral network's sensitization bias and memory for objects or items apart from context (Tucker and Luu, 2012). The dual networks normally work together to enhance complexity and control, as when learning incorporates both habituation and sensitization processes. However, this coordination breaks down under stress. Exactly how each network responds as danger escalates is not known.

Areas of the ventral network are implicated in mood disorders comorbid with stress (Price and Drevets, 2010). Denial (e.g., anosognosia; Ramachandran, 1995) and impulsive acts of suicide fit with Pribram's third person mode and hint at the dorsal network's difficulty with unwanted limitations or loss. Aside from the corticolimbic networks, lower brain regions also respond to traumatizing experiences. Distinct patterns of brain activation inform differential behavioral responses as the brainstem, midbrain, and corticolimbic networks respond to contexts that vary in risk. Cortical regions can initiate preemptive strategies such as "tend and befriend" (Taylor et al., 2000), while the amygdala reacts to present danger and the midbrain PAG directs startle responses. In keeping with dissolution, the more overwhelming a traumatizing experience is the more primitive the brain areas managing it. It is easy to miss primitive associations that only form under survival conditions. To understand these associations, we must appreciate the specific circumstances that elicit them. A traumatized human might

not use the dorsal network that often guides intentional behavior, because the ventral corticolimbic network takes charge at early signs of serious threat. As an inescapable attack becomes imminent, neural activity shifts from overwhelmed cortical areas to brainstem structures such as the PAG (Lanius et al., 2010; Mobbs et al., 2007). This can affect both memory and awareness in humans. As the ventral network detaches from lower brain areas, memory consolidation in that network is disrupted and the symptoms associated with a traumatizing experience would seem anomalous. Measuring just where these shifts occur as threat increases, and how well they correspond to human defensive responses or memory issues, is an important task for clinical research, although we have lacked the clear yardstick to gauge escalating danger that this would require.

When we have a psychobiological reaction to a stressor, our conscious awareness of the psychological and biological elements within this reaction is often uneven (e.g., as in disgust). We are more aware of our mental and emotional processes than of the biological mechanisms that complement them, but stress can limit awareness of any aspect. Specifically, our awareness fails when biological elements operate outside of consciousness, when stress disrupts processes affecting perception or memory, or both. The hierarchical organization of the neuraxis becomes selectively relevant in our varied defensive responses to stress. Severe stress disrupts cortical activity; it impairs the cortical regulation of lower brain areas and the monitoring of peripheral signals. Amygdaloidal (not hippocampal) associations formed during severe stress and unattached to explicit memories would be more difficult for survivors to integrate with their normal experiences. Anamnestic accounts under-report unconscious defenses. This limits the value of conjectures from research participants as to their likely responses during hypothetical danger scenarios. Although we may be unaware of some biological or mental aspects within our stress reactions, and thus unable to name or differentiate them, they can still influence us.

3.2. The peripheral view

One purpose of trauma-related peripheral signals in mammals may essentially be to call for help. Within the neuraxis, primitive areas signal danger and thereby activate the corticolimbic network that is specialized to respond to possible threat. Garcia proposed adding a feedback (FB) term to differentiate the cognitive (CS-US) from motivational (US-FB) aspects of conditioning, thus changing Pavlov's CS-US to CS-US-FB (Garcia, 1990). His US-FB pathway, silent when the dorsal corticolimbic network is dominant, signals unconscious homeostatic evaluative data to overrule previous CS-US associations as the ventral network engages in stress. The periphery can denote a dangerous or life-threatening event that requires central attention, as Schreckstoff and Garcia's results confirm. The body (here, the gut) signals a dangerous context if nausea follows the taste of a new food, even while asleep. The human ventral corticolimbic network is cytoarchitecturally primed to monitor peripheral feedback (Tucker and Luu, 2012).

Data suggest that gut microbes can alter functioning both peripherally, in the enteric nervous system, and centrally, in the brain, thus affecting behavior in both mice and humans (Bravo et al., 2011; Forsythe et al., 2010). Peripheral feedback might follow several internal pathways. Both humoral (cytokine) reactions to stress or infection, and neural signals from the gut or elsewhere in the periphery, can induce central changes (e.g., altered firing rates) designed to regulate peripheral responses (Blalock, 2005). The vagus nerve, with far more afferent than efferent fibers (Agostoni et al., 1957), is suited to relaying visceral chemosensory signals to central autonomic network nuclei in the mammalian CNS (Bravo et al., 2011; Goehler et al., 2000). A third internal path might augment the neural and humoral routes. Extracellular electric fields measured in rat cortical tissue increase the synchronicity of neural firing, with neural responsiveness most sensitive to field oscillations of <8 Hz (Anastassiou et al., 2011). These fields represent a direct route for the brain to monitor peripherally signaled autonomic activation associated with defense states. Visceral signals that denote contexts of danger or life-threat, sensed continuously via heart rate by extracellular fields within the cortex, would inform central processes of defensive needs. Thus, these signals could bias cognitive operations without our awareness. Consider how sensitively our brains alter autonomic activity in response to contexts that we experience as dangerous or life threatening.

The brain selects viable defensive options based on the characteristics of each threat. In environments perceived as safe, people normally respond to others via a social engagement system mediated by the ventral vagus (Porges, 2011). Environments experienced as unsafe evoke an adaptive range of preparatory defenses, mediated sympathetically or dorsal vagally (Porges, 2011). Visceral signals that portend danger or occur in a context of life-threat can alter the subjective perceptions of ambiguous stimuli. For example, physical changes occur in the middle ear when someone does not feel safe. These changes lessen acuity to mid-range (human vocal) frequencies in exchange for adaptively heightened sensitivity to both low and very high-pitched sounds (Porges, 2011). Olfactory signals in the sweat of frightened men bias women to interpret ambiguous facial expressions as more fearful (Zhou and Chen, 2009). Thus, context (specifically, perceived safety or its absence) alters responses to indeterminate stimuli: it constrains options (e.g., which of two forms of learning pertain). Dreams provide a third example. In REM sleep, dreams mitigate the negative affective charge of disturbing experiences, because REM sleep normally suppresses adrenaline and amygdaloid activity (van der Helm et al., 2011). In contrast, REM sleep nightmares in PTSD occur in a milieu of high adrenergic and amygdaloid activation and repeatedly fail to reduce emotional charge (Walker, 2009). Why normal suppression fails in PTSD is unknown (Walker, 2009), but persistent feedback of danger from the periphery or brainstem might countervail normal suppression. Indeed, consolidation of fear extinction memory requires brainstem pontine wave activity during REM sleep in rats (Datta and O'Malley, 2013). Each of these examples illustrates how a signal of danger or safety that comes from the periphery or a primitive brain area can alter central processing in humans.

The parasympathetic nervous system is involved in regulating the HPA axis through two branches of the vagus nerve (Porges, 2011). Specifically, ventral vagal dominance is associated with social engagement in safety. Ventral vagal withdrawal opens the door for sympathetic dominance (Porges, 2011). As the ventral vagus withdraws, sympathetic activity fuels active behavioral responses to escapable or controllable dangers. However, an active defense seldom makes for a viable response to inescapable or uncontrollable threats (e.g., life-threat). When life-threat occurs, dorsal vagal engagement instills immobility (Porges, 2011). (Note that the ventral corticolimbic network and dorsal vagus respond to threats; the dorsal corticolimbic network and ventral vagus may engage during safety.) Consistent with entangled survival systems, varied defensive behavioral options inform immune responses to antigens. Thus, catecholamines are preferentially associated with active defenses while increased cortisol reflects engagement in a context of uncertainty and threat (Henry, 1992). Decreased cortisol in humans marks a reduced threat (Dickerson and Kemeny, 2004) that could follow subsequent disengagement (Mason et al., 2001). In addition, we rarely consider that gut microbes in mammals including humans detect and respond to catecholamines, hence altering susceptibility to infection under stress (Freestone et al., 2007).

Greater attention to specific behavioral defensive responses can deepen awareness of our psychobiological reactions to stress. In the past, anxious stress was thought to impair immune responses

(Kiecolt-Glaser et al., 1998), but now specific defenses appear determinative (Korte et al., 2005). Responses to acute stress facilitate wound healing, while responses to chronic stress impede recovery (Dhabhar, 2009). Hence, defense states may provide the effective yardstick for calibrating these shifting central and peripheral responses to stress that we need. Acknowledging peripheral participation invites us to consider how the brain responds if a traumatized periphery continues to signal threat after a danger has passed. Recall that severe stress inhibits LeDoux's slow neural system and the dorsal corticolimbic network. Primitive brain areas are apt to respond crudely when buffeted by peripheral feedback just as their normal regulation from cortical regions goes offline. After recovery, Garcia's rats appeared surprised by their newfound disgust of saccharine (Garcia, 1990). We may also form associations in survival situations that later we cannot recall having made. Disrupted cortical regulation during severe stress is selectively associated with certain defensive responses in humans and other mammals. Along with survival systems and primitive mechanisms, dissolution plays a role in survival learning.

3.3. Learning in survival conditions

The human brain's vertically organized hierarchical systems are vulnerable to dissolution in survival situations. Disrupted cortical regulation of primitive areas could allow an uncoupling or overcoupling of behavioral and autonomic responses. This can occur permanently following lesions in the orbitofrontal cortex (in marmosets; Reekie et al., 2008) or temporarily in stress via dissolution. With severe stress, peripheral signals become unregulated. Additional information comes from work with spinally transected rats, whose spinal cords are severed from the brain at T2. The spinal cord uses sensitization or habituation to process pain, depending on its controllability (Baumbauer et al., 2009). An experience of uncontrollable shock, physical injury, or inflammation as a neonate has long-term consequences for these paralyzed rats, reducing the learning capacity of their spinal circuits for months. Young et al. (2008) report that immune and inflammatory responses (i.e., sensitization) to such neonatal experiences increase the survival of spinal cells in these rats, while altering their pain reactivity and pain processing into adulthood. Their findings show that simple learning processes both occur and become dysregulated below the brainstem (cf. Bykov, 1957; Razran, 1961). Sensitization impairs habituation in these rats because a release of substance P and its NK1 receptors floods multiple segments of the spinal cord, where it hinders the ability to form specific associations (Baumbauer et al., 2009).

How can it be adaptive to impair the ability to learn? Shared mechanisms explain how sensitization inhibits subsequent plasticity in the spinal cord (Baumbauer et al., 2009). This is a characteristic of entangled systems. Other anomalous yet patently adaptive survival systems involve limbic (emotion) areas such as the amygdala (Garcia, 1990; Garcia et al., 1985), and the fact that the vagus nerve maintains some of these enduring associations (Kiefer et al., 1981) implicates cholinergic involvement and certain defenses. Conditioning normally requires brief inter-stimulus intervals, and conditioned stimuli seldom provoke disgust or fear (Garcia et al., 1984). In contrast, primitive associations can form despite very long inter-stimulus intervals (Garcia, 1990). The specialized US-FB associations processed by the ventral corticolimbic network in stress differ from the CS-US associations of the dorsal network in safety. Habituation and sensitization, immune activation with disgust, and sickness behaviors are all examples of entangled survival systems.

Data available since the inception of the PTSD diagnosis link psychoneuroimmunological processes with trauma-related disorders. Bidirectional communication supports insights not apparent using either the physical explanations of irritable heart or the cognitive explanations of PTSD. During severe stress (i.e., a life-threat), peripheral signals can become uncoupled from the corticolimbic networks that normally guide responses and form our conscious awareness (Mobbs et al., 2009; Tucker and Luu, 2012). Dissolution implies dysregulation. Primitive associations form rapidly and easily, but only in survival conditions; they are often highly specific. For instance, although food aversions occur efficiently when nausea follows a novel taste (Bermudez-Rattoni et al., 1988), nausea does not teach rats to avoid the location where they encountered a poison or the radiation (Garcia et al., 1984). Taste may cause illness. A specialized gut-defense system uses taste and odor to avoid ingesting toxins (Garcia et al., 1985). Vibrations might cause pain. A primitive skin-defense system that is reminiscent of Schreckstoff in vertebrates selectively associates external stimuli with predatory attack (e.g., foot shock; Garcia et al., 1985). Species-specific defense reactions in animals (Bolles, 1970; Brown and Chivers, 2005) and specialized preparedness learning in humans (Cosmides, 1989; Öhman and Mineka, 2001) illustrate the value of biologically restricted response tendencies shaped by survival-related evolutionary pressures. The symptoms of PTSD reflect their shared source: In dire circumstances, immediate needs trump and curtail subsequent abilities.

How we see PTSD can make these symptoms confusing for PTSD sufferers as well as clinicians and researchers. For example, sufferers of PTSD lack a context to understand their intrusive symptoms. Knowing that their intense reactions are disproportionate adds to their distress. Frustrated by the inability to control their unconscious reactions, some even fear going insane. Researchers and clinicians who think of PTSD as a mental disorder rarely consider that symptoms of hypervigilance might stem from sensitization, since this view is not conducive to recognizing primitive mechanisms. Yet, the presence of a form of sensitization in the spinal cords of spinally transected rats, and its long-term reciprocal effects on habituation, support the idea that primitive mechanisms associated with trauma-related disorders can occur below the brainstem. The hypervigilance and intrusive symptoms of PTSD reflect sensitization because that is how our corticolimbic networks negotiate threat. By inhibiting habituation, unregulated sensitization may prolong PTSD as well as other disorders.

Primitive mechanisms operate in survival conditions with intermittent cortical regulation. They offer a basis for understanding comorbidity and the characteristics of trauma-related symptoms. Yet the specialized associations in survival learning are often unseen (Bolles, 1970). Garcia, who studied taste and other aversions decades before the PTSD diagnosis, did not mention implications related to trauma. He noted two practical applications for his discoveries. Wolves fed poisoned mutton rarely kill the sheep on eastern Washington ranches, and children with cancer who receive a novel candy just before each chemotherapy treatment could continue to enjoy their preferred foods (Garcia, 1990). He never explicitly described these aversions as psychobiological reactions in the service of survival. Silove (1998) later implicated ancient and primitive learning mechanisms in the formation of intrusive PTSD symptoms, but cited neither Garcia's work nor interoceptive conditioning as exemplars. Parallels between the hypervigilance symptoms in PTSD and sensitization in pain have also gone unrecognized. Fragmentation and isolation often mark trauma-related issues. The fact that psychobiological mechanisms respond to threat captures a critical but neglected consequence of survival-related traumatic-stress. Outside of this context, variable responses to stress or trauma seem anomalous. They confound the prevailing view. By accepting that there are phylogenetic influences over stress responses, researchers can better identify them. This could advance efforts to treat trauma-related disorders. As will soon become clear, unseen responses to trauma create inexplicable symptom variability.

4. Varied defenses generate varied symptoms

Extensive symptom variability presents a puzzle similar to covariation across disparate diagnoses. The prevailing view does not predict either of these manifestations of variance. It cannot explain the varied symptoms that we see, because it expects traumatizing experiences to evoke active defenses. The diagnostic criteria for PTSD still derive from Cannon (1932), who emphasized sympathetically mediated active responses to threats. Following his lead, we labeled PTSD as an anxiety disorder. Cannon minimized any defensive role for a parasympathetic system that he saw as focused on rest and recuperation. To those sharing this prevailing view, it follows that we should focus on active responses, which means fight and flight. Yet this activist premise does not say what happens when no active defense is viable. The reality of dorsal vagal immobility defenses refutes this view. Together, active and immobility defense states generate varied symptoms as they shift, not just across different people, but also within the same individual over time. An evolutionary view embraces the immobility options that evolved prior to mammalian active defenses (Porges, 2011). Sections 4.1–4.3 describe the panoply of our behavioral defensive options within a changing context of threat imminence.

4.1. Some disregarded defensive options

Pervasive physiological variability arises from differing risk "perceptions," behavioral defense "choices," and autonomic roles (i.e., parasympathetic/sympathetic regulation; Korte et al., 2005). Unfortunately, the literature on human stress responses only intermittently acknowledges the full range of defensive options. Various influential accounts (e.g., Bolles, 1970; Gray and McNaughton, 2000) focus on sympathetically mediated active defenses and dorsal PAG, overlooking the ventrolateral PAG and its more primitive dorsal vagal (immobility) defenses. Hence, the prevailing view selectively disregards autonomically mediated states that evolved to respond to life-threat, which is the most severe category of stress. The minimization of parasympathetic contributions to defensive options, and our failure to distinguish dorsal vagal from ventral vagal influences, have led us to under-appreciate several immobility defenses.

In 1870, Paul Bert discovered bradycardia in ducks (Butler and Jones, 1982) while inadvertently provoking a state of collapse. According to Campbell et al. (1997, p. 55), Bert "forcibly held a duck's head underwater and measured heart rate by feeling the pulsations of the heart through the breast. Submersion produced a sustained decrease in heart rate that persisted until the head was lifted and breathing resumed." Researchers studying the diving reflex assumed that voluntary dives produced cardiovascular and metabolic changes similar to those that occur during forced diving. A century later, telemetered crocodiles in a laboratory revealed dramatic bradycardia when researchers triggered their dives, in contrast to their heart rates during voluntary, undisturbed dives (Gaunt and Gans, 1969). This is how withdrawal (fear) bradycardia was distinguished from diving bradycardia. Fear-related bradycardia is a salient characteristic of collapse, the defense state that primarily responds to overwhelming threat. Yet this form of bradycardia is rarely noticed.

In 1942, Cannon investigated the "Voodoo" death phenomenon. Viewing defenses as sympathetically mediated, Cannon supposed such deaths would stem from the shock of too much adrenaline: "persistent excessive activity of the sympathico-adrenal system" (Cannon, 1942, p. 174). In fact, deaths were caused by parasympathetic over-activity (i.e., collapse). Richter (1957) found that wild rats forced to swim showed decreased respiration and body temperature, and eventually succumbed with the heart in diastole. Later, Hofer (1970) reported very low heart rate, cardiac arrhythmias, and increased respiration during prolonged immobility in four species of recently caught wild rodents exposed to predators in an open area with no ability to escape. This was not long after telemetry data led to our awareness of fear bradycardia (Gaunt and Gans, 1969). Thus, physiological measures consistent with collapse corroborate Richter's results.

The idea that trauma-related disorders involve defensive responses is not new. Rivers (1920) described five "danger-instincts" seen in military survivors of World War I combat: flight, aggression, immobility, and collapse, plus "manipulative activity" meant to avoid, escape, or overcome a threat. However, historical and nosological considerations have coalesced against explicitly incorporating defense states within criteria for trauma-related disorders in the DSM (APA, 1980, 2000, 2013). As a result, trauma-related diagnoses exclude some defense states. There is no coherent rationale for the exclusion. Sporadic efforts to associate these primitive mechanisms with trauma responses have either been incomplete, in that they focused only on sympathetically mediated responses, or unheeded.

Immobility defenses are easy to miss. In addition, these responses to life-threat implicitly remind us of our mortality. Humans react to deeply threatening facts, including reminders of death (Arndt and Vess, 2008; Pyszczynski et al., 1999), with denial. This might contribute to our neglect of immobility defenses. Denial could also be implicated in the "episodic amnesia" (Herman, 1992b) that historically has marked the traumatic-stress field. In order to appreciate fully the dynamics of defense state involvement across trauma-related disorders, it is necessary to see how threat detection, threat appraisal, and defensive options relate to threat imminence.

4.2. A continuum of threat imminence

Mammalian defensive responses take priority over other behaviors under conditions of threat (Fanselow and Lester, 1988). *Predatory imminence* refers to a continuum of perceived danger from predation. This continuum ranges from minimal perceived threat, to predator detection, then predator contact, and escape or death (Fanselow and Lester, 1988). Defenses against predation could have been co-opted to respond to a variety of extreme situations – including abuse, combat, car accidents, and modern disasters. This represents a special case of *threat imminence*, relevant through exaptation (Gould, 1991) to a wide range of traumatic risks. Gould and Vrba (1982, p. 4) first proposed the term *exaptation* to name "features that now enhance fitness but were not built by natural selection for their current role," distinguishing it from adaptation, or those features built by selection for their present role. Adaptation facilitates incremental evolutionary linear change; by contrast, exaptation reveals the quirky diversity and unpredictability (Gould, 1991) that is characteristic of nonlinear change in complex systems.

Most easily characterized in terms of physical distance, predatory imminence is far more subtle. Fanselow and Lester (1988) noted that an approaching predator looking toward its prey is much more dangerous than one looking away or moving at a tangent. Illness or injuries, as well as specific predator characteristics, influence attack vulnerability and thus threat appraisal. Threat imminence is similarly nuanced and subjective. Appraisals of predation or threat shared a subjective element with Criterion A in Acute Stress Disorder (ASD) and in PTSD (e.g., APA, 2000; Fanselow and Lester, 1988; Mobbs et al., 2007). The DSM-5 removed emotional reactions from Criterion A (APA, 2013), but they still occur. Lang et al. (1997) introduced the phrase *defense cascade* to frame the space across which defensive options unfold as threat imminence rises. Defenses begin with the orienting response toward a novel

threatening stimulus (Graham, 1979; Graham and Clifton, 1966; Vila et al., 2003). What happens next depends on the context.

In environments perceived as safe, orienting and motionlessness habituate rapidly. When something changes in such an environment, we resume our activities after a quick glance to make sure this change is not a threat. Orienting to novelty and habituating to prior concerns signifies healthy adaptation in safe environments (Thayer and Friedman, 2002). In a more sketchy setting, detection of novelty signals a need to accommodate to a potential threat by selecting from mutually incompatible defensive responses. Gray's behavioral inhibition system thrives in such settings, where novelty instantiates an approach–avoidance conflict (Gray and McNaughton, 2000). Defensive responses associated with behavioral inhibition habituate slowly (Sánchez-Navarro et al., 2006; Sokolov and Cacioppo, 1997) and prolong stilling. Note that the shift from orienting to defensive responses with a growing risk (e.g., appraising a non-startling stimulus; Graham, 1979) entails a transition from internal intentions to reactive attention or vigilance, befitting a shift to the ventral corticolimbic network. Nonlinear changes in heart rate (Sánchez-Navarro et al., 2006) attend a concomitant interplay of parasympathetic ventral vagal and sympathetic influences. Such changes are well suited to nonlinear analyses (Lafitte et al., 2006).

Together, threat imminence and the defense cascade highlight important contextual contributions to the full range of defense-state variability. Evolutionary views of trauma-related disorders are congruent with comparative and ethological approaches and with embodied psychophysiology research (Critchley, 2005; Dixon, 1998; Gilbert, 2001; Tinbergen, 1974). Investigators employing these approaches routinely observe unconscious indications of defense state activation (e.g., heart rate, muscle tension) in response to stress. Clinicians working with traumatized patients also notice the pertinence of unconscious somatic signs. In contrast, others develop a different understanding. When clinicians or researchers ignore peripheral feedback signals that only respond to threats, they miss nothing as long as their procedures are non-threatening and do not elicit stress responses. However, those focused on central activation (or CS-US associations) might read as superfluous the influence of somatic activation (US-FB) affecting brain activity. From the perspective of someone inattentive to stress, an inoffensive immobility defense (devoid of sympathetic activation) could appear as a tranquil brain. This is partly a matter of selective experience, although a left hemisphere engaged in solving problems does not sense danger or notice issues beyond those deemed relevant (McGilchrist, 2009).

In any case, an early hint of potential danger poses a problem requiring a prompt response. Choices need to weigh the benefits of deflecting or inhibiting a potential attack in advance (e.g., by seeking support), or finding ways to approach, withdraw, or hide from a present threat (Marks, 1987). Some defenses, such as analgesia or nurturance, begin before they are needed. Analgesia is a physiological adjustment that prepares for possible injury without compromising other defenses (Bolles and Fanselow, 1980). Deflecting or inhibiting attack (Marks, 1987) in the absence of immediate danger could avert a future attack. This mammalian strategy is akin to the preemptive "tend and befriend" responses that Taylor et al. (2000) attribute to human females. Yet diverse nurturing behaviors promote safety and reduce distress in both sexes and in a variety of species (Geary and Flinn, 2002; Gilbert, 1995; Marks, 1987). Clearly, the value of each defensive option varies with one's position along a continuum of threat.

4.3. The five defense states

Five defense states emerge, unbidden, when danger is present: freeze-alert, flight, fight, freeze-fright, and collapse, in order of increasing threat imminence. On sensing an unfamiliar stimulus (or before venturing outside), orienting is the best option: "Is it safe?" Freezing (i.e., alarm; alert immobility) is a common, adaptive initial response at *post-encounter*, when the predator is first detected but has not yet seen its prey. Movement attracts attention. Freeze-alert buys time for appraisal while minimizing the risk of detection. Fleeing would tempt the predator to take pursuit. If a predator does not notice movement, they might lose sight of the prey or lose interest – another sound or movement could distract them (Suarez and Gallup, 1981). If the danger escalates to a level of imminent threat, dramatic changes occur as the predator prepares to strike. An active defense (flight, then fight) may emerge here, so long as a subjective appraisal suggests that conditions warrant such actions (Blanchard et al., 2001; Shuhama et al., 2008).

Bracha (2004) identified two variants of the freeze response, here termed freeze-alert and freeze-fright. Some published accounts of "freeze" describe freeze-alert, some freeze-fright, and others blur this distinction. Like the Indian tale of a group of people feeling different parts of the same elephant in a dark room, confusion arises over terminology because authors presume different unnamed variants. It is important to distinguish freeze-alert from freeze-fright because these are distinct autonomic states, responding to differing degrees of appraised threat. Freeze-alert defines an initial and often brief interruption of ongoing activities while appraising early indications of potential danger; it extends the stillness of orienting. Freeze-fright occurs as circa-*strike* approaches or in a context of perceived inescapable threat (e.g., entrapment or life-threat) where it can persist until the threat ends. The freeze-fright state binds immobility with a readiness to act. Paralyzing fear and tonic physical immobility characterize this latter freeze variant, sometimes described as scared stiff (Blanchard and Blanchard, 1969; Marx et al., 2008). Both freeze variants predominate before contact, freeze-alert before and freeze-fright after the predator detects its prey. Both are preferred over flight even when known escape routes are available (Fanselow and Lester, 1988).

Collapse (feigning death) emerges with an overwhelming attack if active defenses are not viable (Bandler et al., 2000; Porges, 2011). A simple thought experiment illustrates these five defensive options. Imagine that you surprise a large bear while alone in the wilderness. Your immediate stillness is the freeze-alert state. If the bear moves off, you can return home with an exciting story for your family. If the bear approaches, your danger deepens. Neither flight nor fight offers a viable option in this and many other cases of extreme threat, where active defenses increase the risk of death. The best option here is freeze-fright, although your chances are slim unless a hunter is nearby. Finally, when the bear has you in its mouth, you are out of options. You go limp in a state of collapse, as described by Livingstone (1857) and others (Levine, 2010). Collapse reduces the likelihood of continued violence, while preparing the individual for injury or death (release of endogenous opioids decreases pain; Bolles and Fanselow, 1980). Immobility is the most effective response during attack because quiescence eliminates auditory and visual cues that elicit or maintain aggression. All of these defense states survive in us from our evolutionary past because each has enhanced the odds of survival.

Hence, the behavioral defensive options are two active and three immobile states. Viewed through a fuzzy lens, the five defensive options appear as two: active and immobile (or passive) (Herman, 1992a; Lanius et al., 2010; Terr, 1991), often corresponding to, and confused with, acute vs. chronic stressors. Knowledge of defensive options allows a reconsideration of the previously mentioned research on connections between immune function and stress responses. For example, Rosenberger et al. (2009) attribute differential healing after knee surgery to varied defensive responses that alter the distribution of immune cells in blood. In their view, short-term stress facilitates wound healing

while chronic stress slows the speed of recovery (Dhabhar, 2009; Rosenberger et al., 2009). Note that these stressors entail active (sympathetic) or immobility (dorsal vagal) defenses, respectively. Recognizing how these distinct defense states affect catecholamine and glucocorticoid patterns could enhance our understanding of the contradictory immune alterations reported across samples of PTSD patients (Pace and Heim, 2011). Identifying not just the active defenses but also all three immobility states in comparative studies might clarify confusion over immune and stress interactions across phyla (Adamo, 2010).

Distinguishing each defense state provides a more accurate picture of the varied responses elicited by differing stressful contexts, making it possible to see through a sharper lens. When defense states unfold as danger escalates, they calibrate the defense cascade. This allows us to link subcortical, limbic and cortical activity to peripheral responses across the threat imminence continuum. Distinguishing the three superficially similar but autonomically distinct immobility defenses yields particularly valuable information. If we limit threat to discrete points (e.g., post-encounter and circa-strike; Mobbs et al., 2009), we neglect some shifts in defensive responses as stress becomes life-threat. Recognizing that there are five defense states should help researchers clarify reported age, behavioral, immune, neuroendocrine, sex, and species differences in response to stressful experiences. This could also improve treatment outcomes.

4.4. Summary: Our evolutionary heritage

An evolutionary view sees that humans inherited ancient psychophysical responses to aid in the service of our survival. Specialized primitive mechanisms serve as elements within imperfectly coordinated survival systems. Phylogenesis and evolutionary constraints gave rise to bidirectional dialog among central and peripheral elements responding to diverse threats. Disruption of these elements during stress creates some puzzling symptoms that may give rise to comorbid physical disorders. In survival situations, dissolution and sensitization operate outside our conscious awareness and can alter our cognition. Differing defensive options are associated with certain midbrain and limbic regions as well as with the corticolimbic networks. Active defenses require cortical activation in support of strategy or tactics, while collapse does not (Llinás, 2001; Mobbs et al., 2007). The insight that trauma-related symptoms are inherently psychobiological expands our perspective on trauma-related disorders. It invites us to consider the involvement of both central and peripheral elements.

The classical conception of the autonomic nervous system presumes a sympathetic branch that is responsive to stress, paired against one parasympathetic branch that is not. This scheme excludes some primitive defense states. In so doing, it minimizes trauma disorders much as Saul Steinberg's *New Yorker* cover, "View of the World from Ninth Avenue," diminished everything west of the Hudson River. Because influential textbooks reiterate this sympathetic bias (e.g., Andreassi, 2007, pp. 64–67), they hinder a wider recognition of vagally mediated immobility defenses and related phenomena such as autonomic dysregulation or dissociation. In addition, the sole English word for "freeze" fails to distinguish two autonomically distinct freeze states. Conflating these states, in turn, obscures important characteristics of all three immobility defenses. Accordingly, popular (e.g., media) attention emphasizes sympathetically mediated defenses such as "fight and flight". Too often, research and clinical efforts do so as well.

Safety and threat denote fundamental contexts. They organize evolutionarily adaptive behaviors (Gilbert, 1993; Porges, 2011). Five autonomically distinct mammalian defense states are mediated by two types of parasympathetic activation (i.e., ventral vagal and dorsal vagal), as well as by sympathetic activity. Humans inherited this panoply of mammalian defenses; any of these states can emerge when stressful experiences exceed our ability to cope. These varied defense states generate the diverse symptoms reported in the traumatic-stress literature. Thus, an evolutionary view resolves some confusion about trauma-related disorders. Applying current knowledge of phylogeny and psychoneuroimmunology will allow scientists and clinicians to further advance the traumatic-stress field. Section 5 details the primitive autonomic patterns associated with specific defense states. Section 6 explores some implications for healthcare.

5. Responding to stress entails defense states

The five defenses – freeze-alert, flight, fight, freeze-fright, and collapse (Bracha, 2004) – are distinct autonomic states. Physiological preparation for flight differs from that for fighting. The three immobility options (both freeze states plus collapse) involve unique patterns of autonomic activation in the service of distinct goals. Dimensions of emotionality and coping style appear independent (Koolhaas et al., 2007). Emotions, such as anger and fear, are not exclusively associated with distinct forms of autonomic activity (Barrett, 2006). Measurement errors surrounding primary and secondary emotions further confuse the issue. Typically, anger is associated with fight and fear or panic with flight, but individuals can fight when afraid, run when angry, and be immobilized when experiencing numbness, anger, or fear. Defenses might or might not involve intense emotions or even awareness; still, the familiarity of emotions and their perceptual salience distracts our attention from any concomitant psychobiology. Numerous anecdotal accounts document the successful use of various active and immobility defenses by survivors of animal attacks, senseless violence, or other traumatizing experiences. Their shifting responses to these threats directly engage dynamically changing autonomic activations. Defense states are the building blocks of this variance. Understanding these primitive states sheds light on our psychobiological reactions to stress and trauma.

5.1. Defense states are autonomically distinct

The autonomic characteristics that define each defense state are described below, in order of increasing threat imminence. Note that the two active defenses typically respond to variations in appraised escapable danger; freeze-fright and collapse respond to varied uncontrollable threats. Ventral vagal dominance during safety contrasts with its absence in all defense states. Descriptions begin with a normal state of safeness, reflecting its importance.

5.1.1. Safety

The experience of safeness promotes parasympathetic ventral vagal dominance. People ideally conduct activities of daily living in this state. In safe environments, ventral vagal activation facilitates social engagement and counteracts unwanted sympathetic arousal (Porges, 2011). Known as the vagal brake, strong ventral vagal activity slows heart rate below the intrinsic rate of the sinoatrial node as we actively engage challenging situations (Porges, 2011). Measures of ventral vagal activity (e.g., heart rate variability, or mutual gaze) reflect resilience, and can gauge how readily social support or psychotherapy alleviates stress in patients. Selye's eustress implies that we can maintain ventral vagal dominance as we cope with challenges.

5.1.2. Freeze-alert

A shift to the freeze-alert defense state occurs when a threat first exceeds our ability to cope. We relinquish parasympathetic control of breathing as ventral vagal withdrawal lifts the vagal brake; the

idiom "bated breath" names the familiar side effect of this involuntary transition to wariness and unfettered sympathetic dominance. Heart rate quickens abruptly in preparation for active defenses. Freeze-alert provides space to assess the nature and degree of any potential threat. It affords time to select among active or immobility options. Sympathetic activity increases the heart rate further (tachycardia) if this state is prolonged. Extended freeze-alert potentiates startle in rats (Leaton and Borszcz, 1985). If movement is called for, it is explosive, "as if the freezing animal is tensed up and ready to explode into action if the freezing response fails it" (Fanselow and Lester, 1988, p. 202). Note that the cardiac symptoms typical of irritable heart (Lewis, 1940) imply an extended freeze-alert state.

5.1.3. Flight and fight

Sympathetic activity mediates both flight and fight. Active defenses, being autonomically interchangeable, can switch fluidly as needed. The differences between these two states involve blood flow (i.e., toward the legs in flight, or to the arms and jaw for fight), facilitating appropriate movements in response to each threat. As mentioned previously, flight or fight is sometimes ill advised. Active defenses epitomize the fundamental motivational systems of withdrawal and approach (Schneirla, 1959).

5.1.4. Freeze-fright

Freeze-fright bespeaks constraint or indecision around the use or timing of active defenses in circumstances already appraised as dire. Pending an active response, coactive (simultaneous) sympathetic with parasympathetic dorsal vagal activity engages the freeze-fright defense state (Henry, 1992; Koizumi et al., 1982; Zhang et al., 2004). Individuals in either freeze state appear as tonically immobile, tense, and primed for movement. Dorsal vagal activity distinguishes freeze-fright from freeze-alert. It inhibits movement, including startle, and may rouse a sense of being unable to move. As Davis and Astrachan (1978) have noted, "at least two processes that have opposite effects on startle must operate as fear increases" (p. 102). Freeze-fright is often accompanied by fear (Fiszman et al., 2008; Fusé et al., 2007; Leach, 2004; Marx et al., 2008). Coactive sympathetic and dorsal vagal activation strengthens heart contractions, increasing blood flow while slightly decreasing heart rate relative to flight or fight (Brooks and Lange, 1982; Koizumi et al., 1982). This is why our hearts pound after a frightening dream. Simulated physical attack (Mobbs et al., 2007) can induce this state in humans.

5.1.5. Collapse

Finally, the hypometabolic defense state of collapse emerges when all other options, whether tried or not, have become futile. In humans, inhaling carbon dioxide under experimental conditions can induce this state (Wetherell et al., 2006). With extreme threat (i.e., inescapable or life-threat), sympathetic activity recedes as the autonomic balance tips to parasympathetic dorsal vagal dominance. The sharply decreased heart rate of bradycardia and a flaccid immobility ("playing dead") signal this transition to collapse (Porges, 2011). The state of collapse is associated with "giving up" amid overwhelming excitation (Engel, 1978). It closely overlaps with "mental defeat" (Ehlers et al., 2000). In the literature, alternate words for collapse include conservation-withdrawal, death feigning, demobilization, faint, hyporesponsiveness, quiescence, submission, syncope, and thanatosis. This plethora of terms reflects a fragmentation in our cultural awareness of the inoffensive state of collapse.

Table 1 lists the five defense states (Bracha, 2004) in order of increasing threat imminence (Fanselow and Lester, 1988; Lang et al., 1997). For each state, autonomic activity (Porges, 2011), somatic or visceral manifestations, and experiential qualities are described. The heart rate ranges presented are for typical adults. Distinct subjective experiences accompany different states and their transitions. Shame may arise from a history of collapse. Moving from freeze-fright to an active defense in psychotherapy entails dorsal vagal discharge (Levine, 1997; Scaer, 2001). Trembling and warmth, at times sufficient to fog up a patient's eyeglasses, can accompany this discharge. Although not indicated in the Table, note that defenses normally shift fluidly in response to changes in threat imminence, including changes in risk cues outside our awareness.

5.2. Defenses sometimes become disorganized

Shifts are not as fluid if defenses are dysregulated. Dysregulation entails inefficient or incomplete shifts between states, and it limits access to more adaptive responses. For example, a rapidly fluctuating heart rate may reflect oscillating sympathetic activity amidst strong dorsal vagal activation, as when freeze-fright vacillates with collapse. Favoring a well-used (or over-learned) defense impairs transitions to other states. Lack of resolution following even a single traumatic experience can generate extended wariness or a quick return to vigilance that persists for months or years. A history of unresolved traumatizing experiences could easily sensitize individuals to the common aspects of these incidents, producing a default state of freeze-alert that looks or feels like anxiety. In either case, the wariness of freeze-alert may extend to normal activities of daily living. Difficulty feeling safe when one is plainly in a safe environment is a common and unsettling indication of this type of dysregulation.

Indeed, previously traumatized individuals with varied diagnoses and assessed under conditions of relative safety often do show signs of the freeze-alert state (Austin et al., 2007; Dale et al., 2009; Hopper et al., 2006; Lampert et al., 2002; Lewis, 1940). Such signs include apprehensiveness in crowds and a tendency to take offense in response to uncertainty or if stressed. These responses are consistent with prolonged hypervigilance and deficient central inhibition of responses to repetitive stimuli (Meares et al., 2011). Developmental or complex traumas often link sensitization and immobility defenses through repeated conditioning; this could disorganize defenses over time. For example, a patient might experience fear at her anger, or grow angry (with self) if afraid. Such complications will be described elsewhere.

Attending to defense states, dysregulated or not, should give researchers a more nuanced understanding of stress responses and enable clinicians to better diagnose trauma-related disorders. In nonlinear terms, the interplay of sympathetic and parasympathetic influences in defense states produce abrupt, saltatory transitions, called bifurcations (Scherer, 2000; Weiner, 1992). Bifurcations mark qualitative shifts in either direction between safety and freeze-alert, between active defenses and freeze-fright, or between freeze-fright and collapse. Dysregulation implies sensitivity to initial conditions and long-term correlations (Heath, 2000; West, 2006). The psychophysical results of stressful experiences may extend well beyond symptoms of mental health. Stressful and traumatizing experiences vary in severity and duration, and they can occur one or many times. If left untreated, the consequences of these events also grow more complex over time. The biological and psychological effects that follow repeated instances of stress and trauma can have profound implications for healthcare, as described below.

6. What this means for healthcare researchers

Considering mental disorders to be rooted in the conscious mind, psychologists have approached these disorders beginning,

Table 1
Defense states: somatic, autonomic, and experiential aspects.

Defense state	Somatic and visceral manifestations	Autonomic activity	Experiential/emotional aspects	References
Safety (contrast)	Relaxed; at ease. Upper face and eyes animated; good eye contact. Hearing tuned to speech sounds. HR: 60–80 bpm, with robust HRV	VVC dominant (vagal brake); SNS varies	Socially engaged; from quiet and calm through activated. Capacity for speech, laughter, play, and tears. Able to self-soothe or seek social support	Gottman (1999), Levenson et al. (1990), McCraty et al. (1995), Porges (2011), Rainville et al. (2006)
Freeze-alert (stillness)	Body stillness. Eyes fixed. Muscles stiff and tense. Throat tight, may "forget" to breathe. Rapid HR increase (to 85 or >90 bpm), with reduced HRV. Potentiated startle may initiate movement	VVC decreased (vagal withdrawal); SNS increases, if prolonged	Alarm; stupefaction; wariness; early fear. Alert, watchful waiting; aware of environment; sensitive to signs of danger. Able to move quickly if needed.	Austin et al. (2007), Leaton and Borszcz (1985), Ogden et al. (2006), Porges (2011), Sánchez-Navarro et al. (2006), Scherer et al. (2004), Vila et al. (2003)
Flight (active)	Leg movements; turning, or backing away. Decreased digestion. Fast respiration; sweating. HR > 100 bpm	SNS strong	Fear or panic; restless. Impulse to run or warn others. Hands are cold	Ax (1953), Ekman et al. (1983), Gottman (1999), Gellhorn and Loofbourrow (1963), Leaton and Borszcz (1985), Perkins and Corr (2006), Quarantelli (1954), Rainville et al. (2006)
Fight (active)	Shoulder, arm, hand, and jaw tense or clenched. Adrenal activity with vasoconstriction. Fast respiration; sweating. HR > 100 bpm	SNS strong	Anger or aggression, perhaps with anxiety. Impulse to kick, hit, or scream. Hands are warm	Ax (1953), Gellhorn and Loofbourrow (1963), Henry (1992), Levenson et al. (1990), McCraty et al. (1995), Ogden et al. (2006), Perkins and Corr (2006), Rainville et al. (2006)
Freeze-fright (immobile)	Body stillness. Eyes fixed. Stomach tension. Tonic (waxy) immobility. HR (~100 bpm), pounding. Fast, shallow, intercostal breathing	DMX and SNS are both strong (coactive)	Hypervigilant. Fear or terror. Alert and aware, but feels paralyzed, unable to move: scared stiff. May be separated from sense of self	Fiszman et al. (2008), Gellhorn and Loofbourrow (1963), Henry (1992), Koizumi et al. (1982), Levenson (1992), Marx et al. (2008), Porges (2011), Quarantelli (1954)
Collapse (immobile)	Flaccid immobility (floppy); eyes averted or glazed. Bradycardia (HR ≤ 60 bpm), shallow slow breathing. Death feigning (playing dead). Syncope or death risk	Sharply reduced SNS (possibly after brief initial burst), leaves strong DMX	Hopeless; giving up; surrender; shame. Detached, trancelike state with impaired orienting. Numbness and analgesia (endo-genous opioids)	Ehlers et al. (2000), Engel (1978), Hofer (1970), Nijenhuis et al. (1998), Porges (2011), Richter (1957)

Key: HR, heart rate; HRV, heart-rate variability; bpm, beats per minute; SNS, sympathetic nervous system; VVC, parasympathetic ventral vagal complex; DMX, parasympathetic dorsal vagal motor nucleus.

and too often ending, with mental explanations. This strategy fails those who are suffering from issues induced or exacerbated by stress, especially when their symptoms look like affective disorders. In order to understand and treat trauma-related disorders properly we need to recognize their psychobiological aspects. Addressing primitive mechanisms that underlie disorders sensitive to stress should increase the treatment possibilities for a wide range of chronic diseases that currently resist healing. This includes some forms of hypertension or pain, and inflammatory disorders such as heart failure or metabolic syndrome. Stress-related disorders should respond well to treatments that span the artificial line between the mental and the physical. Looking ahead, we could integrate a systems biology approach, using personalized biomedical data to guide treatment and automated biofeedback to alter interoceptive conditioning in or below the brainstem. We could focus on any defense reactions aroused by medical procedures through education or therapy, while also developing medications specifically targeted to facilitate progress (e.g., learning) within the psychotherapeutic process. These steps would boost treatment efficacy and reduce costs.

A full recovery was unlikely for someone diagnosed with irritable heart. Is it that much more certain now for soldiers returning from multiple combat deployments or adults exposed to early child abuse? The cost of treating traumatized individuals underscores a continuing need to boost treatment efficiency. Recognition of trauma-related disorders as psychobiological might reduce the social stigma experienced by persons with these issues, and encourage them to seek help earlier. Too often, adult survivors blame themselves for becoming weak (immobile) when stressed, not realizing that this now dysregulated defense began in childhood when freeze-fright or collapse was their only viable option. A more accurate model of the range of defense states evoked in traumatizing experiences would help survivors better understand their responses, reducing needless distress. The following three sections detail implications for stress research (Section 6.1), clinical practice (Section 6.2), and diagnostic nosology (Section 6.3).

6.1. Implications for stress research

Decoding how subcortical, cortical and peripheral areas interact and respond to escalating stress is a crucial task for researchers. Defense states provide a means to probe these links. Institutional review boards might be more apt to approve proposals for research seeking to use moderate rather than extreme stressors, a bias that pulls for active defenses and sympathetic activity. Studies that utilize moderately stressful events could still evoke unpredictable and diverse defenses. Defenses vary when participants have unknown histories of traumatization or if they display varied sensitivities to particular kinds of stress. Immobility responses involve parasympathetic activity. Discriminating both freeze states and collapse

requires differentiating between ventral vagal and dorsal vagal activation. If only sympathetic activity is deemed relevant, then freeze-fright is confused with fight or flight while collapse states would easily be mistaken for tranquility or even rejected as artifact. This applies to stress research with any mammal, including humans. For example, animal researchers define the freeze response as a count or duration of observed motionlessness. This reliable measure potentially conflates three distinct immobility states, not only hindering attempts to delineate animal models for PTSD, but muddling efforts to study the stress responses of mammals.

People of different ages and genders likely have differing access to defensive options. Varied PTSD symptoms and incidence rates, currently attributed to age or gender status, might instead reflect the unequal viability of defense states for persons in these groups. This alternative has not been examined. For example, Jackson et al. (2006) used skin conductance as a measure of the stress response and concluded that a prior stressful condition (similar to the Trier Social Stress Test) modulates fear conditioning differentially in men and women. It might, but this study confounds gender with (mostly unmeasured) defenses. Skin conductance, a common measure of the sympathetic stress response, does not capture ventral vagal withdrawal or dorsal vagal activation and so misses parasympathetic aspects of freeze-alert, freeze-fright, and collapse. Jackson et al. used a single stressor and did not measure vagal aspects of the stress response, so alternate explanations remain viable. The genders may engage dissimilar defense states to this or many stressors. Conditioning efficiency could vary with defense state, with gender, or with their interaction. These researchers found that men with higher salivary cortisol showed enhanced fear conditioning even after their cortisol levels were no longer elevated, although self-reported anxiety failed to predict conditioning in men or women. Heightened cortisol implies motivated performance against uncontrollable threats (Dickerson and Kemeny, 2004). Assessing all defensive responses across diverse stressors (with both sensitization and habituation), perhaps using a Brunswikian representative design, could clarify this issue.

Researchers studying the heart under stress have two options. They can reject as artifact episodes of bradycardia from cardiac data before analysis. That option restricts, a priori, the ability to detect collapse in response to stressors. Alternately, they can analyze heart rate data intact. This option increases variance that appears as noise, reducing statistical power to detect meaningful differences in response to changing levels of stress. Holmes et al. (2004) may have encountered the noise problem. In their study, carefully screened dissociative participants in control conditions watched a "trauma video" of graphic traffic accidents and then recorded intrusions for a week thereafter. In two out of the three experiments they conducted, the average heart rates of 30 and 16 participants, recorded and synced to the film, slowed significantly (by 1.6 and 1.9 beats per minute [bpm]; standard deviation [SD] 2.49 and 3.08) as the participants viewed segments they subsequently recorded as intrusive. These moments of peak distress were termed "hot spots". The change in heart rate was akin to skipping a beat (Brewin, personal communication, 16 November 2004). Skipped beats might indicate collapse or autonomic dysregulation: for instance, an inefficient transition between defense states. In the third experiment, the average heart rate of 13 participants was 4.3 bpm slower during these hot spots, but that decrease did not reach significance because the variance tripled (SD 9.25). However, hot spots imply either freeze-fright or collapse, and combining those states would sharply increase variance. This speculation underscores a central point: Identifying and differentiating among the immobility states is very difficult unless we assess their signature autonomic patterns.

6.2. Implications for clinical practice

Traumatizing events evoke defense states. Traumatized individuals in states of freeze or collapse may appear quite still, but the collapsed patients present as more flaccid or acquiescent and less tense or distressed. Mutual eye contact is most evident in safety. Gaze, normally fixed in either freeze state, averts in collapse. Patients in collapse might speak hopelessly of giving up. They regularly feel disgust, helplessness, or shame. Some report bodily and emotional anesthesia (Nijenhuis et al., 1998). See Table 1 for additional descriptions. Among patients with unrevealed trauma histories, however, defenses that masquerade as other disorders hinder diagnosis. For example, when such patients readily shift into an immobility state they are unlikely to be identified as having shifted into a defense state linked to unresolved trauma. Busy healthcare workers, unaware of a patient's trauma history or its relevance, could confuse collapse with depression or either freeze state with anxiety. Reports of alternations among those states might suggest a history of bipolar episodes. In addition, treating patients solely with medications when they hold (unrecognized) trauma is unlikely to resolve their real issues. Thus, treatment efficacy can be unduly compromised when a traumatized person is incorrectly diagnosed with a disorder unrelated to stress. This bias seems particularly frequent in primary medical practices or intensive care units, where trauma-related symptoms are common and often ignored (Davydow et al., 2008; Lecrubier, 2004; Neria et al., 2008).

The lesson for clinicians working with patients on known trauma issues is that effective psychotherapy requires recognizing defense states as they emerge and shift. While experienced trauma therapists respond intuitively to signs of somatic activation, teaching attunement to defense states certainly should advance the training of trauma-informed clinicians. Primitive mechanisms respond well to unexpected interventions, such as EMDR (Ramachandran, 1995). Trauma-focused somatic awareness approaches can access and alter concomitant psychophysical responses. Relaxation aids in the processing of traumatic material (Elofsson et al., 2008), and should benefit dysregulated patients. Foa and Kozak (1986) found that numbing (suggesting collapse) impeded cognitive processing during trauma therapy. This appears reasonable. The reduced cortical activity sometimes seen as traumatized dissociative individuals reach collapse (Lanius et al., 2010) implies a lessened capacity to process information during stress. Managing defense-state shifts during psychotherapy sessions and gearing specific interventions to distinct defenses requires that clinicians adjust methods quickly. Interrupted active defenses may need to complete, whereas boundary work, centering, and rehearsal of active coping skills while in a ventral vagal or freeze-alert state could develop adaptive options prior to habitual collapse (Brantbjerg, personal communication, 12 October 2008). Clearly, the considerations and clinical methods brought to bear in informed and trauma-focused psychotherapy diverge from and extend those used in cognitive-behavioral therapy or the original talking cure.

Attention to defenses provides a reliable definition of clinical success, since increased ventral vagal activity marks the return to a state of safety. However, research on treatment efficacy and the procedural codes for psychotherapy sessions both fail to recognize some unique features of trauma-informed therapy. First, evaluating treatment interventions with respect to specific diagnostic categories is misguided and discards valuable data. Assessments of trauma-focused interventions need to account for defense states. Specific defenses emerge under stress, with little regard for diagnostic categories. When defense states do emerge, they can moderate the effectiveness of medication (Fiszman et al., 2008). Notably, not one "evidence-based" psychotherapeutic approach

for trauma-related disorders has been evaluated for its efficacy in treating defense states. Hence, none can show evidence of efficacy with specific defenses. Second, concurrent physiological monitoring assists in tracking real time shifts of autonomic states during a therapy session. Physiological monitoring clearly aids in diagnosis, assessment, and treatment of patients with defense state involvement; e.g., it allows for contingent responses in virtual therapy or by clinicians. Traumatized patients also benefit from extended (~90 min) sessions, to access dorsal vagal activation and allow time for settling. However, some payers had denied previous Current Procedural Terminology (CPT) codes for physiological monitoring as experimental, or extended psychotherapy sessions as unnecessary. CPT codes were revised for 2013, without input from trauma organizations. The current codes reduce session lengths. There is no code for a 90-min session, either with or without physiological monitoring.

6.3. Implications for nosology

The comorbidities observed between traumatization and multiple physical disorders are more closely associated with the degree of traumatization (including the number of lifetime traumas, or subthreshold PTSD) than with the PTSD diagnosis itself (Pietrzak et al., 2011; Sledjeski et al., 2008). Piecemeal explanations fail to clarify the scope or dynamics of associations with either symptom or comorbid forms of variability. Certainly, both internal (i.e., individual; Griffin et al., 1997; Osuch et al., 2001) and external (e.g., types of trauma, Herman, 1992a; Terr, 1991) factors are sources of variability, but these static factors cannot fully explain either form. Rather, both symptom variability and comorbid disorders appear to emerge from the varied reactions of entangled psychobiological survival systems to diverse threats.

Several proposals to differentiate simple from more complex forms of PTSD (e.g., Ford, 1999; Herman, 1992a; Lanius et al., 2010; van der Kolk et al., 1996), based largely on differing prognoses and salient aspects of traumatic events, have yet to be incorporated within the DSM. Complex PTSD is associated with victims held captive or unable to flee during prolonged or repeated traumatizing experiences. The prognosis of those diagnosed with Complex PTSD is poorer than it is for those with simple PTSD. From an evolutionary perspective, it should be no surprise that Complex PTSD is the more difficult disorder to treat, since the defense states involved are still virtually unrecognized. Simple PTSD arises from incomplete or interrupted active defenses (i.e., sympathetic activity alone). Complex PTSD stems from freeze-fright or collapse (i.e., dorsal vagal activation, with or without sympathetic activity). The proposed variants of PTSD appear to reflect distinct disorders arising from appropriately dissimilar responses to fundamentally different predicaments (danger vs. life-threat). Note that defense states provide a psychophysical structure for clinical distinctions such as these.

An evolutionary outlook could provide a useful conceptual framework for stress-related disorders in the DSM (Bracha and Maser, 2008), which currently neglects mammalian defenses and treats similar symptoms as comparable whether they arise from stress or not. The arousal symptoms in PTSD (Cluster E in the DSM-5; APA, 2013) reflect sympathetic activation, but all defense states exhibit arousal except for collapse. Some traumatizing incidents engage active defenses that fail to complete. Others evoke immobility defenses. Repetition may entail autonomic dysregulation or even disorganization. Now, these cases are all combined in a single disorder. Denoting stress-related symptoms and disorders in terms of specific defenses would codify PTSD and other trauma-related disorders along evolutionarily relevant dimensions, increasing diagnostic sensitivity and perhaps revealing candidate endophenotypes. The DSM-5 moved PTSD to a chapter on Trauma- and Stressor-Related Disorders and added a dissociative subtype (APA, 2013). These are small but important steps forward. On the other hand, as long as this diagnosis fails to recognize its underlying psychophysical dynamics, its symptoms seem to lack commonality and we will continue to miss clinically meaningful expressions of distress.

7. Conclusions and perspective

Historically, the early trauma-related diagnoses emphasized physical signs. PTSD shifted the focus to mental signs, but problems remain because trauma-related symptoms are inherently psychobiological. Psychoneuroimmunological data that describe bidirectional communication among entangled survival systems shed light on a false dichotomy; these data can advance our understanding of comorbidity. Likewise, contemporary conceptions of the autonomic nervous system explain the diversity of observed symptom variability. A balanced appreciation of the psychophysical contributions to trauma symptoms will only emerge as we see symptoms in the light of current facts.

Traumatizing experiences tap defensive responses associated with danger and life-threat. Viewing trauma within an evolutionary framework respects peripheral influences, and accepts a wide range of defensive behaviors. These diverse reactions to trauma and the varied symptoms in trauma-related disorders appear anomalous outside of their evolutionary context. Variance associated with defense state transitions is well suited for nonlinear analyses in two ways. First, autonomic parameters constrain bifurcations among defense states. Second, their complex oscillations are dynamic, entangled, recurring, and sensitive to initial conditions. Attending to the full range of defensive options will deepen our understanding of these variable responses to stress. The historical controversies over clinical approaches to managing trauma, as well as disagreements over the efficacy of trauma-focused interventions, might have stemmed from variability in the heretofore-undelineated defensive states of patients.

New perceptions can change the meaning of well-known facts (Hanson, 1961). Barrett (2006) argues that naive assumptions have spread confusion and hobbled the study of emotion. The traumatic-stress field could be ripe for a similar re-conceptualization. By pointing out the consequences of narrow premises, I hope to turn attention toward some primitive mechanisms that are involved when stress induces or exacerbates diverse symptoms. Science usually advances by gradually accreting new data, but accommodating fresh ideas brings a different kind of progress (Kuhn, 1970). Scientific ideas gain credibility when they allow researchers to solve important problems. An evolutionary perspective offers real solutions because it sees both phylogenetic and psychobiological influences on trauma-related disorders. This broader view could guide not just approaches to biopsychosocial treatment, but approaches to research.

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