Dysregulation of the right brain: a fundamental mechanism of traumatic attachment and the psychopathogenesis of posttraumatic stress disorder

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Objective: This review integrates recent advances in attachment theory, affective neuroscience, developmental stress research, and infant psychiatry in order to delineate the developmental precursors of posttraumatic stress disorder.
Method: Existing attachment, stress physiology, trauma, and neuroscience literatures were collected using *Index Medicus/Medline* and *Psychological Abstracts*. This converging interdisciplinary data was used as a theoretical base for modelling the effects of early relational trauma on the developing central and autonomic nervous system activities that drive attachment functions.
Results: Current trends that integrate neuropsychiatry, infant psychiatry, and clinical psychiatry are generating more powerful models of the early genesis of a predisposition to psychiatric disorders, including PTSD. Data are presented which suggest that traumatic attachments, expressed in episodes of hyperarousal and dissociation, are imprinted into the developing limbic and autonomic nervous systems of the early maturing right brain. These enduring structural changes lead to the inefficient stress coping mechanisms that lie at the core of infant, child, and adult posttraumatic stress disorders.
Conclusions: Disorganised-disoriented insecure attachment, a pattern common in infants abused in the first 2 years of life, is psychologically manifest as an inability to generate a coherent strategy for coping with relational stress. Early abuse negatively impacts the developmental trajectory of the right brain, dominant for attachment, affect regulation, and stress modulation, thereby setting a template for the coping deficits of both mind and body that characterise PTSD symptomatology. These data suggest that early intervention programs can significantly alter the intergenerational transmission of posttraumatic stress disorders.
Key words: attachment, child abuse, dissociation, right brain, trauma.

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A recent large, nationally representative study reports that 60% of men and 50% of women experience a traumatic event at some point in their lives [1]. And yet this same study finds that estimates of lifetime posttraumatic stress disorder (PTSD) are 5% for men and 10% for women. Other research indicates that roughly only one half of those who have an episode of PTSD develop chronic symptoms of the disorder [2]. These data underscore a central problem – although trauma is a common element of many if not most lives, why do only a certain minor proportion of individuals exposed to the various forms of trauma develop chronic pathological reactions of mind and body to catastrophic life events?

A major change in our approach to this problem is reflected in the shift from DSM-III-R where the severity

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of the trauma was considered to be the key factor in precipitating PTSD, to DSM-IV where characteristics of the victim, including the reaction to the trauma, is emphasised. In other words, the aetiology of PTSD is best understood in terms of what an individual brings to a traumatic event as well as what he or she experiences afterward, and not just the nature of the traumatic event itself [3]. This clearly implies that certain personality patterns are specifically associated with the unique ways individuals cope or fail to cope with stress.

Current psychobiological research on PTSD echoes this principle [4]:

> Although many people are exposed to trauma, only some individuals develop PTSD; most do not. It is possible that humans differ in the degree to which stress induces neurobiological perturbations of their threat response systems, which may result in a differential capacity to cope with aversive experiences (p.412) . . . These individual differences exist before trauma exposure and may be used to test constructs of stress hardiness and stress vulnerability in humans (p.420).

There is now agreement that the developmental stage at the time of exposure [5] and the specific type of trauma exposure [6] are essential factors in PTSD, and yet they have been de-emphasised in the recent literature [7]. Highlighting these factors however, brings into the foreground a number of fundamental issues. What are the short and long-lasting effects of trauma in the earliest developmental stages, why does this exposure negatively impact the maturation of the individual's stress coping systems, and how is this related to the genesis of premorbid personality organisations vulnerable to posttraumatic stress disorder? These questions, which lie at the core of trauma theory, direct clinical psychiatry into the realms of child and especially infant psychiatry.

Attachment and the development of right brain stress coping mechanisms

In fact the exploration of the early development of adaptive coping mechanisms and of the personality is at the core of attachment theory, 'the dominant approach to understanding early socioemotional and personality development during the past quarter-century of research' [8, p.145]. In his groundbreaking volume, *Attachment*, John Bowlby [9] hypothesised that the infant's 'capacity to cope with stress' is correlated with certain maternal behaviours, and that attachment outcome has consequences that are 'vital to the survival of the species.' Bowlby's speculation that, within the attachment relationship, the mother shapes the development of the infant's coping responses is now supported by a large body of experimental studies that characterise maternal care and the development of stress responses [10], and the influence of maternal factors on the ontogeny of the limbic-hypothalamic-pituitary-adrenal axis [11].

Recent developmental psychobiological models indicate that,

> An individual's response to stressful stimuli may be maladaptive producing physiological and behavioral responses that may have detrimental consequences, or may be adaptive, enabling the individual to better cope with stress. Events experienced early in life may be particularly important in shaping the individual's pattern of responsiveness in later stages of life [12, p.1435].

These 'events' are attachment experiences, shaped by the interaction of the infant's innate psychophysiological predispositions and the social environment of maternal care [13–22].

Furthermore, current basic stress research suggests that deprivation of maternal care represents a source of 'stressful environmental information' for the developmental, maturational pattern of the neural circuitry of the infant's stress system [23]. This complements studies indicating that pre or postnatal stressors negatively impact later mental health, especially when maternal care is absent. Such work is derivative of attachment theory's deep interest in the aetiology of not only normal but also abnormal development. In applying the theory to links between stress coping features and psychopathology Bowlby [24] proposed:

> In the fields of aetiology and psychopathology [attachment theory] can be used to frame specific hypotheses which relate different family experiences to different forms of psychiatric disorder and also, possibly, to the neurophysiological changes that accompany them.

In this work I will apply this central principle of attachment theory to the aetiology of posttraumatic stress disorder. Although aetiological models of PTSD have centred primarily on childhood sexual abuse, I will suggest that an increased focus on the neurobiological consequences of relational abuse and dysregulated infant attachment can offer a deeper understanding of the psychoneurobiological stress coping deficits of both mind and body that define the symptomatic presentation of the disorder.

Stress and the right hemisphere

A growing body of current evidence shows that the neural circuitry of the stress system is located in the early developing right brain, the hemisphere that is dominant for the control of vital functions that support survival and the human stress response [25]. Because stress

coping strategies are deeply connected into essential organismic functions, they begin their maturation pre- and postnatally, a time of right brain dominance [26]. A very recent MRI study of infants reports that the volume of the brain increases rapidly during the first 2 years, that normal adult appearance is seen at 2 years and all major fibre tracts can be identified by age 3, and that infants under 2 years show higher right than left hemispheric volumes [27]. Attachment experiences of the first 2 years thus directly influence the experience-dependent maturation of the right brain [14,21,28–32]. These include experiences with a traumatising caregiver, which are well known to negatively impact the child's attachment security, stress coping strategies, and sense of self [33,34].

Indeed, current studies in developmental traumatology now conclude that 'the overwhelming stress of maltreatment in childhood is associated with adverse influences on brain development' [35, p.1281]. This 'maltreatment' specifically refers to the severe affect dysregulation of the two dominant forms of infant trauma – abuse and neglect. There is much support for the principle that social stressors are far more detrimental than nonsocial aversive stimuli [36], and therefore attachment or 'relational trauma' from the social environment has more negative impact upon the infant brain than assaults from the nonhuman or inanimate, physical environment. and so it is now being emphasised that specifically a dysfunctional and traumatised early *relationship* is the stressor that leads to PTSD, that severe trauma of interpersonal origin may override any genetic, constitutional, social, or psychological resilience factor, and that the ensuing adverse effects on brain development and alterations of the biological stress systems may be regarded as 'an environmentally induced complex developmental disorder' [37].

The fact that such trauma is 'ambient' clearly suggests that the infant is frequently experiencing not single episode or acute but 'cumulative' and chronic unpredictable traumatic stress in his very first interactions with another human. The stress literature, which is now investigating 'determinants of individual differences in stress reactivity in early development' clearly shows that acute stress produces short-term and reversible deficits, while repeated, prolonged, chronic stress is associated with long-term patterns of autonomic reactivity, expressed in 'neuronal structural changes, involving atrophy that might lead to permanent damage, including neuronal loss' [38, p.183]. Consonant with this principle, in earlier writings I have suggested that early relational trauma has a significant negative impact on the experience-dependent maturation of the right brain, which is in a critical period of growth during the same temporal intervals as dyadic attachment experiences [14,39–44].

Because the early developing right hemisphere is, more so than the later maturing left, deeply interconnected into the autonomic, limbic, and arousal systems, it is dominant for the processing of social emotional and bodily information [14,45–47]. A large number of studies now indicate that this hemisphere is dominant not only for the reception [48–51], expression [52], and communication [53] of emotion, but also for the control of spontaneously evoked emotional reactions [54], the modulation of 'primary emotions' [55], and the adaptive capacity for the regulation of affect [14,18,56].

It has been said that the most significant consequence of the stressor of early relational trauma is the lack of capacity for emotional self-regulation [57], expressed in the loss of the ability to regulate the intensity and duration of affects [58]. Basic developmental neuropsychobiological studies now indicate that perinatal distress leads to a blunting of the stress regulating response of the right (and not left) prefrontal cortex that is manifest in adulthood [59]. In light of the essential role of the right hemisphere in the human stress response, this psychoneurobiological conception of trauma-induced right brain pathogenesis bears upon recent data which suggest that early adverse experiences result in an increased sensitivity to the effects of stress later in life and render an individual vulnerable to stress-related psychiatric disorders [60]. Affect dysregulation is now seen to be a fundamental mechanism of all psychiatric disorders [61].

A developmental neuropsychopathological perspective dictates that 'To understand neuropsychological development is to confront the fact that the brain is mutable, such that its structural organisation reflects the history of the organism' [62, p.297]. A history of early relational traumatic stress is specifically imprinted into the right brain, which is dominant for 'autobiographical' [63] or 'personal' [64] memory. Terr [65] writes that literal mirroring of traumatic events by behavioural memory can be established at any age, including infancy. This developmental model suggests that traumatic attachments, occurring in a critical period of organisation of the right brain, will create an enduring vulnerability to dysfunction during stress and a predisposition to post-traumatic stress disorders.

Right brain dysregulation, dissociation, and PTSD pathogenesis: introduction

Indeed, in 1996 van der Kolk [66] proposed that the symptoms of PTSD fundamentally reflect an impairment of the right brain, known to be dominant for inhibitory control [67]. This hypothesis subsequently received experimental support in a number of studies [68–70]. In this same period dysfunction of the frontal lobes,

specifically the orbitofrontal system that is expanded in the right hemisphere [71] and controls instinctive emotional responses through cognitive processes, was also implicated in PTSD [72–75]. This line of research has continued in very recent studies that show right hemispheric and orbitofrontal dysfunction in PTSD [69,76–79].

The emotional disturbances of PTSD have been suggested to have their origins in the inability of the right prefrontal cortex to modulate amygdala functions [18,44,80,81], especially activity of the right amygdala [82], known to process frightening faces [83,84] and 'unseen fear' [85]. LeDoux concludes that without orbital prefrontal feedback regarding the level of threat, the organism remains in an amygdala-driven defensive response state longer than necessary [86], that in humans, conditioned fear acquisition and extinction are associated with right hemisphere dominant amygdala function [87], and that a defective orbitofrontal system operates in PTSD [88].

In the present period we are also seeing a parallel interest in developmental research on the aetiology of the primitive defence that is used to cope with overwhelming affective states – dissociation. From the perspective of developmental psychopathology, an outgrowth of attachment theory that conceptualises normal and aberrant development in terms of common underlying mechanisms, dissociation is described as offering 'potentially very rich models for understanding the ontogeny of environmentally produced psychiatric conditions' [89, p.582]. Disorganised-disoriented insecure attachment, a primary risk factor for the development of psychiatric disorders [90], has been specifically implicated in the aetiology of the dissociative disorders [91].

Neuroscience is now delving into the neurobiology of dissociation, especially in infancy [44,92]. It is currently thought that dissociation at the time of exposure to extreme stress signals the invocation of neural mechanisms that result in long-term alterations in brain functioning [93]. This principle applies to long-term alterations in the developing brain, especially the early maturing right brain, the locus of dissociation [44,94], withdrawal and avoidance [95], and a spectrum of psychiatric disorders [29,39,96].

Traumatic attachment, dysregulation, and the pathogenesis of PTSD

Bowlby postulated that the major negative impact of early traumatic attachments is an alteration of the organism's normal developmental trajectory. Over 30 years ago he wrote [9],

> [S]ince much of the development and organization of [attachment] behavioral systems takes place whilst the individual is immature, there are plenty of occasions when an atypical environment can divert them from developing on an adaptive course.

And 70 years earlier, Pierre Janet [97] proposed

> All [traumatized] patients seem to have the evolution of their lives checked; they are attached to an insurmountable object. Unable to integrate traumatic memories, they seem to have lost their capacity to assimilate new experiences as well. It is . . . as if their personality development has stopped at a certain point, and cannot enlarge any more by the addition of new elements.

Janet further postulated that the psychological consequence of trauma is the breakdown of the adaptive mental processes leading to the maintenance of an integrated sense of self. Again, recent studies indicate that the right hemisphere is central to self-recognition [98] and the ability to maintain a coherent, continuous, and unified sense of self [47], but it also is the locus of various self-regulation pathologies [14,29,30].

The concept of regulation, now shared by the attachment, PTSD, neuroscience, and psychiatric literatures, may be a bridging concept for expanding a biopsychosocial model of psychiatry. According to Taylor, Bagby, and Parker,

> The concept of disorders of affect regulation is consistent with a growing realization in medicine and psychiatry that most illnesses and diseases are the result of dysregulations within the vast network of communicating systems that comprise the human organism [61, p.270].

A model of the interactive genesis of psychobiological dysregulation also supports and provides a deeper understanding of the diathesis-stress concept – that psychiatric disorders are caused by a combination of a genetic-constitutional predisposition and environmental or psychosocial stressors that activate the inborn neurophysiological vulnerability. The unique contributions of the intrinsic psychobiological perspective of trauma studies to both clinical psychiatry and neuroscience is articulated by McFarlane:

> [T]he origins of psychiatry in medicine tie the discipline strongly to its biological roots. The field of traumatic stress has the potential to bridge this divide . . . Traumatic stress as a field, has the capacity to show the future direction of functional neurobiology [99, p.900,901].

In a recent editorial in the *American Journal of Psychiatry* entitled 'The development of neurodevelopmental psychiatry', Rapoport [100] calls for deeper

studies of the association between pre/perinatal adverse events or stressors and adult psychiatric outcomes. Towards that end, in the following I will suggest that recent theoretical models linking developmental affective neuroscience and attachment theory, updated basic research in biological psychiatry on stress mechanisms, and current advances in psychophysiology on the survival functions of the autonomic nervous system may offer us a deeper understanding of the underlying mechanisms by which early childhood trauma massively dysregulates and thereby alters the developmental trajectory of the right hemisphere. This results in an immature personality organisation with vulnerable coping capacities, one predisposed to the pathological hyperarousal and dissociation that characterises PTSD at later points of stress. These psychoneurobiological models, which link infant, child, and adolescent psychiatry, are offered as heuristic proposals that can be evaluated by experimental and clinical research.

Overview of the neurobiology of a secure attachment

The essential task of the first year of human life is the creation of a secure attachment bond of emotional communication between the infant and the primary caregiver. In order to enter into this communication, the mother must be psychobiologically attuned to the dynamic crescendos and decrescendos of the infant's bodily based internal states of autonomic arousal. During the sequential signalling of play episodes mother and infant show sympathetic cardiac acceleration and then parasympathetic deceleration in response to the smile of the other, and thus the language of mother and infant consist of signals produced by the autonomic, involuntary nervous system in both parties [101]. The attachment relationship mediates the dyadic regulation of emotion [102], wherein the mother coregulates the infant's postnatally developing autonomic nervous system. Also known as the vegetative nervous system, from the Latin, *vegetare*, to animate or bring to life, it is responsible for the generation of what Stern [103] calls vitality affects.

In heightened affective moments each partner learns the rhythmic structure of the other and modifies his or her behaviour to fit that structure, thereby cocreating a specifically fitted interaction. In play episodes of affect synchrony, the pair are in affective resonance, and in such, an amplification of vitality affects and a positive state occurs especially when the mother's psychobiologically attuned external sensory stimulation frequency coincides with the infant's genetically encoded endogenous rhythms. and in moments of interactive repair the 'good-enough' caregiver who induces a stress response in her infant through a misattunement, reinvokes in a timely fashion a reattunment, a regulation of the infant's negative state. Maternal sensitivity thus acts as an external organiser of the infant's biobehavioural regulation [104].

If attachment is the regulation of interactive synchrony, stress is defined as an asynchrony in an interactional sequence, and, following this, a period of re-established synchrony allows for stress recovery and coping. The regulatory processes of affect synchrony that creates states of positive arousal and interactive repair that modulates states of negative arousal are the fundamental building blocks of attachment and its associated emotions, and resilience in the face of stress is an ultimate indicator of attachment security. Attachment, the outcome of the child's genetically encoded biological (temperamental) predisposition and the particular caregiver environment, thus represents the regulation of biological synchronicity between organisms, and imprinting, the learning process that mediates attachment, is defined as synchrony between sequential infant-maternal stimuli and behaviour.

The optimally regulated communications embedded in secure attachment experiences directly influence the maturation of both the postnatally maturing central nervous system (CNS) limbic system that processes and regulates social-emotional stimuli and the autonomic nervous system (ANS) that generates the somatic aspects of emotion. The limbic system derives subjective information in terms of emotional feelings that guide behaviour [105], and functions to allow the brain to adapt to a rapidly changing environment and organise new learning [106]. As mentioned, the higher regulatory systems of the right hemisphere form extensive reciprocal connections with the limbic and autonomic nervous systems [107,108]. Both the ANS and the CNS continue to develop postnatally, and the assembly of these limbic-autonomic circuits [109] is directly influenced by the attachment relationship [14,18]. In this manner, the internalised regulatory capacities of the infant develop in relation to the mother, and thus, as Bowlby suggested, the mother shapes the infant's stress coping systems.

Attachment and right cortical regulation of the autonomic nervous system

In his original formulation Bowlby [9] described a neurophysiological control system that is centrally involved in regulating instinctive attachment behaviour [31,101]. In a number of writings I indicate that this system is located in the right orbitofrontal area and its cortical and subcortical connections [14,16,18,29,31,

45,56,110]. Due to its position at the interface of the cortex and subcortex, this ventromedial cortex sits at the highest level of the limbic system. It directly connects into the subcortical reticular formation, thus regulating arousal, a central component of all emotional states. Indeed this prefrontal system acts the highest level of control of behaviour, especially in relation to emotion [111]. Referred to as 'the thinking part of the emotional brain', it is situated at the hierarchical apex of what is now referred to as the 'rostral limbic system' [112], or 'anterior limbic prefrontal network' [113], which also includes the anterior cingulate (medial frontal cortex) and the amygdala [18,45]. This 'Senior Executive' of the social-emotional brain comes to act in the capacity of an executive control function for the entire right brain, the locus of the emotional self [47].

But in addition, the orbitofrontal cortex also represents the apex of the hierarchy of control of autonomic functions [114]. Due to its direct connections into the hypothalamus, the head ganglion of the ANS, It functions as a cortical control centre of involuntary bodily functions that represent the somatic components of all emotional states, and acts to control autonomic responses associated with emotional events [115]. Recent studies demonstrate that operation of the right prefrontal cortex is integral to autonomous regulation, and that the right hemisphere is dominant for the processing and regulation of self-related information and the corporeal self [14,45,47,98,116].

In optimal early environments that promote secure attachments, a right lateralised regulatory system organises with a capacity to modulate, under stress, a flexible coping pattern of shifting out of autonomic balance into a coupled reciprocal autonomic mode of control in which homeostatic increases in the activity in one ANS division are associated with decreases in the other [117]. The two components of the centrally regulated ANS are known to be distinct modular circuits that control arousal expressions, with the catabolic sympathetic branch responsible for energy-mobilising excitatory activity and the anabolic parasympathetic branch involved in energy-conserving inhibitory activity. These dissociable autonomic functions reflect the sympathetic catecholaminergic stimulation of glycogenolysis and parasympathetic vagal and cortisol stimulation of glycogenesis [118–120].

In light of the fact that primordial representations of body states are the building blocks and scaffolding of development [121], the current intense interest in emotional development is now beginning to focus increasing attention upon changes in bodily state, mediated by the ANS, that are crucial to ongoing emotional experience. The right hemisphere, dominant for somatosensory processing [122], predominantly controls both sympathetic and parasympathetic activity [123,124]. The ANS, by regulating the strength of the heartbeat and controlling vascular calibre, performs a critical role in ensuring that bloodflow is adequate to supply oxygen and nutrients to the bodily organs and the brain, according to their relative needs.

A quick review of the ANS indicates that the sympathetic branch is activated by any stimulus above an organismic threshold, and that it functions to increase arousal, trigger an immediate anticipatory state, and rapidly mobilise resources in response to appraised stressors. Physiological activation is expressed in the conversion of glycogen to glucose and elevation of blood sugar for increased energy, quicker and stronger heart beat, increased blood supply to the muscles, dilation of bronchii and increases in breathing rate, dilation of the pupils, increased sweating, and speeding up of mental activity. The opposing parasympathetic branch has a higher threshold of activation and thus initiates its operations after the sympathetic, and its adaptive functions are expressed in slowing the heart rate, relaxing the muscles, lowering blood pressure, and pupillary constriction. Its operations allow for breathing to return to normal rates, increases in digestion, onset of bowel and bladder activities, and re-establishment of immune functions.

An autonomic mode of reciprocal sympathetic-parasympathetic control is behaviourally expressed in an organism that responds alertly and adaptively to a personally meaningful (especially social) stressor, yet as soon as the context is appraised as safe, immediately returns to the relaxed state of autonomic balance. In very recent thinking, the ANS is not only sensitive to environmental demands and perceived stresses and threats, but will, in a predictable order, also rapidly reorganise to different neural-mediated states [125, p.20]. These ANS changes are regulated by 'higher' limbic structures in the CNS. Indeed the orbitofronta1 cortex acts as a major centre of CNS control over the sympathetic and parasympathetic branches of the ANS [126], and thereby regulates autonomic responses to social stimuli [127], the intuitive 'gut feelings' that an individual has to other humans. These right lateralised connections also mediate the adaptive capacity of empathically perceiving the emotional states of other human beings [14,18,29, 110,128].

The early forming right hemisphere stores an internal working model of the attachment relationship [14,21] that determines the individual's characteristic strategies of affect regulation for coping and survival [14,20]. This working model is encoded in implicit memory, which is primarily regulatory, automatised, unconscious [129], and right lateralised [130]. This right frontal system thus

plays a unique role in the regulation of motivational states and the adjustment or correction of emotional responses. It acts as a recovery mechanism that monitors and regulates the duration, frequency, and intensity of not only positive but also negative affect states.

In the securely attached individual this representation encodes an implicit expectation that homeostatic disruptions will be set right, allowing the child to self-regulate functions which previously required the caregiver's external regulation. In this manner, emotion is initially regulated by others, but over the course of early development it becomes increasingly self-regulated as a result of neurophysiological development [131]. These adaptive capacities are central to self-regulation, the ability to flexibly regulate emotional states through interactions with other humans – interactive regulation in interconnected contexts, and without other humans – autoregulation in autonomous contexts.

The orbitofrontal attachment control system is specialised to play a critical role in strategic memory by supporting the early mobilisation of effective behavioural strategies in novel or ambiguous situations [132]. Operating at levels beneath awareness, it is activated when there is insufficient information available to determine the appropriate course of action, and is specialised to act in contexts of 'uncertainty or unpredictability' [133], an operational definition of stress. Efficient orbitofrontal operations organise the expression of a regulated emotional response and an appropriate motivational state for a particular social environmental context, and in this fashion it contributes to 'judicious, adapted behaviour' [115]. Anatomical, electrophysiological, and imaging studies indicate that the orbitofrontal functions are central to 'the integration of past, present, and future experiences, enabling adequate performance in behavioural tasks, social situation, or situations involving survival' [134, p.356]. As mentioned earlier, current neuroscience research indicates that these same adaptive stress-survival capacities are severely impaired in infant, child, and adult posttraumatic stress disorders.

The neurobiology of infant trauma

It is important to stress that the developmental attainment of an efficient internal system that can adaptively regulate various forms of arousal and psychobiological states, and thereby affect, cognition, and behaviour, only evolves in a growth-facilitating emotional environment. The good-enough mother of the securely attached infant permits access to the child after a separation and shows a tendency to respond appropriately and promptly to his/her emotional expressions. She also allows for the interactive generation of high levels of positive affect in coshared play states. These regulated events allow for an expansion of the child's coping capacities, and account for the principle that security of the attachment bond is the primary defence against trauma-induced psychopathology.

In contrast to this scenario is a relational growth-inhibiting early environment, in which the abusive caregiver not only shows less play with her infant, but also induces traumatic states of enduring negative affect in the child. Because her attachment is weak, she provides little protection against other potential abusers of the infant, such as the father. This caregiver is inaccessible and reacts to her infant's expressions of emotions and stress inappropriately and/or rejectingly, and therefore shows minimal or unpredictable participation in the various types of arousal regulating processes. Instead of modulating she induces extreme levels of stimulation and arousal, very high in abuse and/or very low in neglect. and because she provides no interactive repair the infant's intense negative states last for long periods of time.

The enduring detrimental effects of parent-inflicted trauma on the attachment bond is now well-established:

> The continued survival of the child is felt to be at risk, because the actuality of the abuse jeopardizes [the] primary object bond and challenges the child's capacity to trust and therefore to securely depend [135, p.62].

Freyd [136], in describing the effects of childhood abuse and attachment, refers to 'betrayal trauma theory'.

In contexts of relational trauma the caregiver[s], in addition to dysregulating the infant, withdraw any repair functions, leaving her for long periods in an intensely disruptive psychobiological state that is beyond her immature coping strategies. In studies of a neglect paradigm, Tronick and Weinberg [137, p 56], describe:

> When infants are not in homeostatic balance or are emotionally dysregulated (e.g. they are distressed), they are at the mercy of these states. Until these states are brought under control, infants must devote all their regulatory resources to reorganizing them. While infants are doing that, they can do nothing else.

The 'nothing else' these authors refer to is a failure to continue to develop. These infants forfeit potential opportunities for socioemotional learning during critical periods of right brain development [44].

Indeed, we now know that trauma causes biochemical alterations within the developing brain [39]. The infant's psychobiological response to trauma is comprised of two separate response patterns, hyperarousal and dissociation [44,138]. In the initial stage of threat, a startle or an alarm reaction is initiated, in which the sympathetic

component of the ANS is suddenly and significantly activated, resulting in increased heart rate, blood pressure, and respiration. Distress is expressed in crying and then screaming. In very recent work, this dyadic transaction is described by Beebe as 'mutually escalating overarousal' of a disorganised attachment pair [139, p.436]:

> Each one escalates the ante, as the infant builds to a frantic distress, may scream, and, in this example, finally throws up. In an escalating overarousal pattern, even after extreme distress signals from the infant, such as 90 degree head aversion, arching away . . . or screaming, the mother keeps going.

The infant's state of 'frantic distress', or what Perry [138] terms fear-terror is mediated by sympathetic hyperarousal, expressed in increased levels of the brain's major stress hormone, corticotropin releasing factor, which in turn regulates sympathetic catecholamine activity [140], and so brain adrenaline, noradrenaline, and dopamine levels are significantly elevated. Noradrenaline is also released from the locus coeruleus [141,142]. The resultant rapid and intensely elevated catecholamine levels trigger a hypermetabolic state within the developing brain. Catecholamines are among the first neurochemicals to respond to stressors in response to perceived threat, and repeated stress triggers their persistent activation [143]. Prolonged stress and elevated levels of catecholamines in turn induce high levels of thyroid hormones that accompany hyperarousal [32,144]. Thyroid hormones are known to be active agents in brain differentiation and in the regulation of critical period phenomena [14,145,146].

In addition, increased amounts of vasopressin are expressed, a hypothalamic neuropeptide associated with sympathetic activation [147,148]. This condition is specifically triggered when an environment is perceived to be unsafe and challenging, and resultant high levels of vasopressin potentiate immobilisation responses via sympathetic activation, behaviourally expressed as fear [125]. Interestingly, high levels of this neuropeptide are associated with nausea [149], a finding that may explain the hyperarousal behaviours observed by Beebe.

But a second later forming reaction to infant trauma is seen in dissociation, in which the child disengages from stimuli in the external world and attends to an 'internal' world. The child's dissociation in the midst of terror involves numbing, avoidance, compliance and restricted affect (the same pattern as adult PTSD). Traumatised infants are observed to be 'staring off into space with a glazed look'. This behavioural strategy is described by Tronick and Weinberg [137, p.66]:

> [W]hen infants' attempts fail to repair the interaction infants often lose postural control, withdraw, and self-comfort. The disengagement is profound even with this short disruption of the mutual regulatory process and break in intersubjectivity. The infant's reaction is reminiscent of the withdrawal of Harlow's isolated monkey or of the infants in institutions observed by Bowlby and Spitz.

This parasympathetic dominant state of conservation-withdrawal occurs in helpless and hopeless stressful situations in which the individual becomes inhibited and strives to avoid attention in order to become 'unseen' [14,44]. This metabolic shutdown state is a primary regulatory process, used throughout the life span, in which the stressed individual passively disengages in order 'to conserve energies . . . to foster survival by the risky posture of feigning death, to allow healing of wounds and restitution of depleted resources by immobility' [150, p.213]. It is this parasympathetic mechanism that mediates the 'profound detachment' [151] of dissociation. If early trauma is experienced as 'psychic catastrophe' [152], dissociation represents 'detachment from an unbearable situation' [153], 'the escape when there is no escape' [154], and 'a last resort defensive strategy' [155].

Most importantly, the neurobiology of the later forming dissociative reaction is different than the initial hyperarousal response. In this passive state pain numbing and blunting endogenous opiates [156] and behaviour-inhibiting stress hormones, such as cortisol, are elevated. Furthermore, activity of the dorsal vagal complex in the brainstem medulla increases dramatically, decreasing blood pressure, metabolic activity, and heart rate, despite increases in circulating adrenaline. This elevated parasympathetic arousal, a survival strategy [157], allows the infant to maintain homeostasis in the face of the internal state of sympathetic hyperarousal.

It is now known that there are two parasympathetic vagal systems, a late developing 'mammalian' or 'smart' system in the nucleus ambiguus which allows for the ability to communicate via facial expressions, vocalisations, and gestures via contingent social interactions, and a more primitive early developing 'reptilian' or 'vegetative' system in the dorsal motor nucleus of the vagus that acts to shutdown metabolic activity during immobilisation, death feigning, and hiding behaviours [125,157]. Porges describes that as opposed to the ventral vagal complex that can rapidly regulate cardiac output to foster engagement and disengagement with the social environment, the dorsal vagal complex 'contributes to severe emotional states and may be related to emotional states of "immobilisation" such as extreme terror' [157, p.75]. Perry's description of the traumatised infant's sudden state switch from sympathetic hyperarousal into parasympathetic dissociation is reflected in Porges' characterisation of:

> . . . the sudden and rapid transition from an unsuccessful strategy of struggling requiring massive sympathetic activation to the metabolically conservative immobilized state mimicking death associated with the dorsal vagal complex [157, p.75].

Meares [158] also concludes that in all stages 'dissociation, at its first occurrence, is a consequence of a "psychological shock" or high arousal.' Notice that in the traumatic state, and this may be of long duration, both the sympathetic energy-expending and parasympathetic energy-conserving components of the infant's developing ANS are hyperactivated.

Disorganised/disoriented attachment neuropsychology

The next question is, how would the trauma-induced neurobiological and psychobiological alterations of the developing right brain be expressed in the socio-emotional behaviour of an early traumatised toddler? In a classic study, Main and Solomon [159] studied the attachment patterns of infant's who had suffered trauma in the first year of life. This lead to the discovery of a new attachment category, 'Type D', an insecure-disorganised/disoriented pattern, one found in 80% of maltreated infants [160]. Indeed this group of toddlers exhibits higher cortisol levels and higher heart rates than all other attachment classifications [161,162].

Main and Solomon conclude that these infants are experiencing low stress tolerance and that the disorganisation and disorientation reflect the fact that the infant, instead of finding a haven of safety in the relationship, is alarmed by the parent. They note that because the infant inevitably seeks the parent when alarmed, any parental behaviour that directly alarms an infant should place it in an irresolvable paradox in which it can neither approach, shift its attention, or flee. At the most basic level, these infants are unable to generate a coherent behavioural coping strategy to deal with this emotional challenge.

Main and Solomon documented, in some detail, the uniquely bizarre behaviours these 12-month-old infants show in Strange Situation observations. They note that these episodes of interruptions of organised behaviour are often brief, frequently lasting only 10–30 s, yet they are highly significant. For example, they show a simultaneous display of contradictory behaviour patterns, such as 'backing' towards the parent rather than approaching face-to-face.

> The impression in each case was that approach movements were continually being inhibited and held back through simultaneous activation of avoidant tendencies. In most cases, however, proximity-seeking sufficiently 'over-rode' avoidance to permit the increase in physical proximity. Thus, contradictory patterns were activated but were not mutually inhibited [159, p.117].

Notice the simultaneous activation of the energy expending sympathetic and energy conserving parasympathetic components of the ANS.

Maltreated infants also show evidence of apprehension and confusion, as well as very rapid shifts of state during the stress-inducing Strange Situation. These authors describe:

> One infant hunched her upper body and shoulders at hearing her mother's call, then broke into extravagant laugh-like screeches with an excited forward movement. Her braying laughter became a cry and distress-face without a new intake of breath as the infant hunched forward. Then suddenly she became silent, blank and dazed [159, p.119].

These behaviours generalise beyond just interactions with the mother. The intensity of the baby's dysregulated affective state is often heightened when the infant is exposed to the added stress of an unfamiliar person. At a stranger's entrance, two infants moved away from both mother and stranger to face the wall, and another 'leaned forehead against the wall for several seconds, looking back in apparent terror'.

These infants exhibit 'behavioural stilling' – that is, 'dazed' behaviour and depressed affect, behavioural manifestations of dissociation. One infant 'became for a moment excessively still, staring into space as though completely out of contact with self, environment, and parent.' Another showed 'a dazed facial appearance . . . accompanied by a stilling of all body movement, and sometimes a freezing of limbs which had been in motion'. Yet another 'fell face-down on the floor in a depressed posture prior to separation, stilling all body movements'.

Furthermore, Main and Solomon point out that the type 'D' behaviours take the form of stereotypes that are found in neurologically impaired infants. These behaviours are overt manifestations of an obviously impaired regulatory system, one that rapidly disorganises under stress. Notice that these observations are taking place at 12–18 months, a critical period of corticolimbic maturation [14], and they reflect a severe structural impairment of the orbitofrontal control system that is involved in attachment behaviour and state regulation. The orbitofrontal areas specialise in encoding information [163], especially information contained in emotionally expressive faces and voices, including angry and fearful faces [133,164].

The mother's face is the most potent visual stimulus in the child's world, and it is well known that direct gaze can mediate not only loving but powerful aggressive messages. In coding the mother's frightening behaviour Hesse and Main [165, p.511], describe 'in nonplay contexts, stiff-legged "stalking" of infant on all fours in a hunting posture; exposure of canine tooth accompanied by hissing; deep growls directed at infant.' Thus, during the trauma, the infant is presented with an aggressive expression on the mother's face. The image of this aggressive face, as well as the chaotic alterations in the infant's bodily state that are associated with it, are indelibly imprinted into limbic circuits as a 'flashbulb memory', and thereby stored in imagistic procedural memory in the visuospatial right hemisphere, the locus of implicit [130] and autobiographical [63] memory.

But in traumatic episodes the infant is presented with another effectively overwhelming facial expression, a maternal expression of fear-terror. Main and Solomon [159] note that this occurs when the mother withdraws from the infant as though the infant were the source of the alarm, and they report that dissociated, trancelike, and fearful behaviour is observed in parents of type 'D' infants. Current studies show a link between frightening maternal behaviour and disorganised infant attachment [166].

I suggest that during these episodes the infant is matching the rhythmic structures of the mother's dysregulated states, and that this synchronisation is registered in the firing patterns of the stress-sensitive corticolimbic regions of the infant's brain that are in a critical period of growth. In light of the fact that many of these mothers have suffered from unresolved trauma themselves, this spatiotemporal imprinting of the chaotic alterations of the mother's dysregulated state facilitates the downloading of programs of psychopathogenesis, a context for the intergenerational transmission of trauma. This represents a fundamental mechanism by which maladaptive parental behaviour mediates the association between parental and offspring psychiatric symptoms [167], and parental PTSD and parental trauma exposure impact the child's development of a risk factor for PTSD [168].

Impact of relational trauma on right brain development

In an early history of traumatic attachment the developing infant/toddler is too frequently exposed to a massively misattuning primary caregiver who triggers and does not repair long lasting intensely dysregulated states. These negative states reflect severe biochemical alterations in the rapidly maturing right brain, and because they occur during the brain growth spurt [169], the effect of ambient cumulative trauma is enduring. In the infant brain, states become traits [138], and so the effects of early relational trauma as well as the defences against such trauma are embedded into the core structure of the evolving personality. According to Bowlby the effect of an atypical environment is that development is diverted from its adaptive course. This leads to the question, what do we now know about the psychopathomorphogenetic mechanisms that underlie such deflections of normal structural development?

The developing infant is maximally vulnerable to nonoptimal environmental events in the period of most rapid brain growth. During these critical periods of genetically encoded synapse overproduction followed by environmentally driven synapse elimination, the organism is sensitive to conditions in the external environment, and if these are outside the normal range a permanent or semipermanent arrest of development occurs. Of particular importance is the identification of various stressful 'growth-inhibiting environments' that negatively influence the critical period organisation of limbic cortical and subcortical connections that mediate homeostatic self-regulatory and attachment systems. Disruption of attachment bonds in infant trauma leads to a regulatory failure, expressed in an impaired autonomic homeostasis, disturbances in limbic activity, and hypothalamic and reticular formation dysfunction. Developmental psychobiological studies indicate that hyperaroused attachment stressors are correlated with elevated levels of the arousal-regulating catecholamines and hyperactivation of the excitotoxic *N*-methyl-D-aspartate (NMDA)-sensitive glutamate receptor, a critical site of neurotoxicity and synapse elimination in early development [170].

The relational trauma of infant abuse also triggers significant alterations in the major stress regulating neurochemicals, corticotropin releasing factor and the glucocorticoid, cortisol, especially in the right hemisphere that is dominant for the secretion of these hormones [171,172]. Yehuda points out that the actions of these two systems are synergistic: 'whereas catecholamines facilitate the availability of energy to the body's vital organs, cortisol's role in stress is to help contain, or shut down sympathetic activation' [173,p 257]. It is now well established that stress hormones are protective in the short run and yet cause damage when they are overproduced or not shut off when no longer needed [38]. There is a large body of basic research to show that both stress hormones are regulated (for better or worse) within the mother-infant relationship (see [14]).

In situations where the caregiver routinely does not participate in reparative functions that re-establish

homeostasis, the resulting psychobiological disequilibrium is expressed in a dysregulated and potentially toxic brain chemistry, especially in limbic areas that are in a critical period of synaptogenesis. Indeed, this same interaction between high levels of catecholamines, excitatory transmitters, and corticosteroids is now thought to mediate programmed cell death [174], and to represent a primary aetiological mechanism for the pathophysiology of neuropsychiatric disorders (see [39,44] for a detailed account of trauma-induced altered calcium metabolism and oxidative stress damage in neurones and astroglia in the developing brain).

But in addition, when the attachment trauma exhausts the infant's active coping mechanisms, she shifts into hypoarousal and accesses the ultimate survival strategy, dissociation, 'a submission and resignation to the inevitability of overwhelming, even psychically deadening danger' [135]. If this primary metabolic shutdown becomes a chronic condition, it will have devastating effects on the morphogenesis of limbic structures. Dissociation and conservation-withdrawal, functional expressions of heightened dorsal vagal activity, induce an extreme alteration of the bioenergetics of the developing brain. During critical periods of regional synaptogenesis this would have growth-inhibiting effects, especially in the right brain which specialises in withdrawal and contains a vagal circuit of emotion regulation. This is because the biosynthetic processes that mediate the growth and proliferation of synaptic connections in the postnatally developing brain demand, in addition to sufficient quantities of essential nutrients, massive amounts of energy [14,39,45]. An infant brain that is chronically shifting into hypometabolic survival modes has little energy available for growth.

In describing the dorsal vagal complex Porges states that when all else fails, the nervous system elects a metabolically conservative course; this strategy may be adaptive in the short term, but lethal if maintained. He also notes that high levels of dorsal vagal activation are associated with 'potentially life-threatening bradycardia, apnea, and cardiac arrhythmias' [125, p.14]. This may describe stresses on the infant's cardiovasculature and developing blood–brain barrier during and after relational trauma. I have suggested that in the developing brain this 'lethality' is expressed in intensified cell death in 'affective centres' in the limbic system [39].

As opposed to the excitotoxic cell death associated with elevated levels of corticosteroids, prolonged and intense dorsal vagal activity may be associated with profoundly low corticosteroid levels, also known to impair brain development in limbic structures [175]. Hypocortisolism develops subsequent to extended periods of elevated cortisol in response to trauma, and adverse conditions in early life that induce elevated levels of cortisol are now proposed to contribute to the development of hypocortisolism in adulthood [176], a known predictor of PTSD [177]. Recall that abused type 'D' infants show higher cortisol levels than all other attachment classifications [161]. It should be pointed out that infants raised in a neglectful environment show a low cortisol pattern of circadian cortisol production [176]. This suggests different neurobiological impairments and neurophysiological deficits in the two types of infant trauma – abuse and neglect.

In other words, the caregiver's dysregulating effect on the infant's internal state, and her poor capacity to psychobiologically regulate excessive levels of high and/or low arousal negative affect, defines a pathomorphogenetic influence. Structural limitations in the mother's emotion processing right brain are reflected in a poor ability to comfort and regulate her child's affective states, and these experiences, central to the intergenerational transmission of psychopathology, are stamped into the insecurely attached infant's right orbitofrontal system and its cortical and subcortical connections. Harkness and Tucker [178] state that the early traumatic experiences of childhood abuse, literally kindle limbic areas. In this manner, early adverse developmental experiences may leave behind a permanent physiological reactivity in limbic areas of the brain [179], thereby inhibiting its capacity to cope with future stressors.

In light of the fact that males, due to delayed rates of cerebral maturation, are more susceptible than females to a large number of conditions that impair the developing brain, and that the limbic system of males and females show different connectivity patterns, gender differences in developmental traumatology must be considered. These factors indicate that by nature of their CNS and ANS immaturity males may be more susceptible to relational abuse, and that the dysregulation of early abused males is psychobiologically biased more towards hyperarousal, and females more towards dissociation. These would endure as permanent limbic reactivities that underlie gender predispositions to externalising and internalising disorders.

The infant posttraumatic stress disorder episodes of hyperarousal and dissociation imprint the template for later childhood, adolescent, and adult posttraumatic stress disorders, all of which show disturbances of autonomic arousal [180], abnormal catecholaminergic function [181,182], neurologic soft signs [183], and dissociation [44]. This would be symptomatically expressed as a cycling between intrusive hypersympathetically driven terrifying flashbacks and traumatic images and parasympathetically driven dissociation, avoidance, and numbing. Recent models of PTSD refer to stressor-induced

oscillations between traumatic and avoidant states, and cycling between the bidirectional symptoms of emotional reexperiencing and emotional constrictedness [184].

Trauma-induced excessive pruning of right brain circuits

Even more specifically, social-emotional environments that provide traumatising attachment histories retard the experience-dependent development of frontolimbic regions, especially the right cortical areas that are prospectively involved in affect regulating functions. These descending projections from the prefrontal cortex to subcortical structures are known to mature during infancy, and relational traumatic experiences could induce a severe and extensive pruning of higher limbic connections (orbitofrontal, anterior cingulate, and amygdala) into the arousal centres in the reticular formation and autonomic centres in the hypothalamus via a 'kindling' [185] mechanism (see [44], Fig. 3).

Relational trauma-induced developmental overpruning of a corticolimbic system, especially one that contains a genetically encoded underproduction of synapses, represents a scenario for high-risk conditions. It is now established that 'psychological' factors 'prune' or 'sculpt' neural networks in the postnatal brain. In earlier works I have suggested that excessive pruning of hierarchical cortical-subcortical circuits operates in the aetiology of a vulnerability to later extreme disorders of affect regulation [14,29,39,44]. In the last decade, a growing body of neurobiological research on PTSD has uncovered dysfunctional frontal-subcortical systems [186,187], and altered functional activity of the orbitofrontal cortex [69,75], anterior cingulate [188,189], and amygdala [68].

An extensive parcellation of axonal connections between orbitofrontal and catecholaminergic areas of the midbrain and medullary reticular formation would lead to a predisposition for arousal dysregulation under stress. At the same time severe pruning of its hypothalamic connections would lead to inefficient regulation of the ANS by higher centres in the CNS [39,44], functionally expressed in a dissociation of central regulation of sympathetic and hypothalamic-pituitary-adrenal systems [190]. This loss means that under stress a coupled reciprocal mode of autonomic control would give way to a coupled nonreciprocal mode of autonomic control, resulting in an intensely high state of sympathetic plus parasympathetic arousal. Severe dysregulation of both central and autonomic arousal is a hallmark of posttraumatic stress disorders.

Supporting this model, a growing body of research demonstrates orbitofrontal dysfunction in PTSD [69,77–79]. Recall, this system is specialised to show a flexible response in stressful contexts of uncertainty. The right orbitofrontal system is thought to act as the neural basis by which humans control their instinctive emotional responses through cognitive processes, and the emotional disturbances of PTSD are proposed to have their origins in the inability of the right prefrontal cortex to modulate amygdala functions [80]. What could be the origin of a defective 'rostral limbic system'?

Over the course of postnatal development connections between the orbitofrontal cortex and amygdala increase, and this hierarchical organisation allows this prefrontal system to take over amygdala functions [191], and for the right frontotemporal cortex to maintain inhibitory control over intense emotional arousal [192]. But early traumatic attachment intensifies the parcellation of these right lateralised connections, and so in posttraumatic stress disorders, when orbitofrontal inhibitory control is lost, activity of the right amygdala [193], known to nonconsciously process frightening faces [83] and 'unseen fear' [85] drives the right brain system. Current work on the neurobiology of stress suggests that chronic stress contributes to atrophy of specifically the prefrontal cortex and amygdala [38].

It is now established that a pathological response to stress reflects the functions of a hyper-excitable amygdala [194], that fear-potentiation of startle is mediated through the amygdala, which directly projects to the brainstem startle centre [195], and that the memory processes of the amygdala are amplified by extreme stress [196]. These amygdala-driven startle and fear-freeze responses would be intense, because they are totally unregulated by the orbitofrontal (and medial frontal) areas that are unavailable for the correction and adjustment of emotional responses. In poorly evolved right brain systems of PTSD-vulnerable personalities even low intensity interpersonal stressors could activate unmodulated terrifying and painful bodily based dysregulated experiences of the individual's early history that are imprinted into amygdalar-hypothalamic limbic-autonomic circuits. Early memory is now being understood as a residual of the basic mechanisms of brain maturation. According to Valent [20] early handling and misattunements may be deeply remembered physiologically in later life in the form of disconnected physiological responses, emotions, and acting out, a description that mirrors van der Kolk's [66] assertion that 'the body keeps the score'.

In light of the findings that autonomic changes in the body are evoked when angry facial expressions are subliminally presented at levels beneath awareness to the right and not the left hemisphere [197], and that the right amygdala is preferentially activated by briefly presented, subliminal faces [198] and specialised for the expression

of memory of aversively motivated experiences [199], I suggest that subliminal [200] visual and auditory stressors emanating from faces, processed in an inefficient right hemisphere, the locus of the startle mechanism [201], are potent triggers of dysregulation and dissociation in early traumatised patients. Of special importance is the very rapid right brain perception [51,202] and memory retrieval [203,204] of visual images and prosodic tones of voice that emanate from subjectively perceived threatening and humiliating faces [44,205]. Notice that the dysregulated implicit process more so than the specific explicit conscious content of the traumatic memory reveals the underlying pathological mechanism.

The right, as opposed to the left amygdala is activated when the individual is not consciously aware of the aversive nature of a nonverbal eliciting stimulus, one that still triggers an immediate negative representation [206]. Loss of modulating function of the right anterior cingulate, located anterior and inferior to the amygdala, would interfere with its known role in inducing a relaxation of bodily states of sympathetic arousal [207]. Loss of higher orbital corticolimbic regulation would lead to a deficit in distinguishing between mental representations of ongoing reality and currently irrelevant memories [208]. When dissociated from these 'top-down' influences, an 'exaggerated amygdala' response to masked facially expressed fearful reminders of traumatic events occurs in PTSD patients [209].

Thus in these flashback moments, a right subcortically driven traumatic re-enactment encoded in implicit memory would occur in the form of a strong physiological autonomic dysregulation and highly aversive motivational state of terror and helplessness, 'without reference to reality', and for 'no apparent reason.' In other words, the person would not be aware that his fear has any origin in space, place, and time. This bears upon McFarlane and Yehuda's observation, 'Essentially, the core of traumatic syndromes is the capacity of current environmental triggers (real or symbolic), to provoke the intense recall of affectively charged traumatic memory structures, which come to drive current behaviour and perception' [7, p.900]. I would add that a focus on 'cumulative' relational instead of 'single-hit' trauma emphasises that the traumatic event of the PTSD patient originated as a personal and social process, thereby suggesting that the 'affectively charged traumatic memory' is not of a specific overwhelming experience with the physical environment as much as a re-evocation of a prototypical disorganised attachment transaction with the misattuning social environment that triggers an intense arousal dysregulation.

Indeed, there is now evidence to show that early relational trauma is particularly expressed in right hemispheric deficits in the processing of social-emotional and bodily information. Very recent studies reveal that maltreated children diagnosed with PTSD manifest right lateralised metabolic limbic abnormalities [210], and that right brain impairments associated with severe anxiety disorders are expressed in childhood [211]. Adults severely abused in childhood [212] and diagnosed with PTSD [77] show reduced right hemisphere activation during a working memory task. Neurological studies of adults confirm that dysfunction of the right frontal lobe is involved in PTSD symptomatology [213] and dissociative flashbacks [78]. Current neuropsychiatric research indicates that the paralimbic areas of the right hemisphere are preferentially involved in the storage of traumatic memories [214], that altered right-sided activity occurs in panic and social phobic anxiety states [215,216], and that dissociation reflects a deficiency of right brain functioning [94]. Neurobiological research thus suggests continuity in the expression of the stress coping deficits of posttraumatic stress disorders over the course of the life span.

Continuity between infant, childhood, and adult PTSD

In parallel work clinical researchers are describing a continuity in infant and adult coping deficits [217, p.253]:

> The stress responses exhibited by infants are the product of an immature brain processing threat stimuli and producing appropriate responses, while the adult who exhibits infantile responses has a mature brain that . . . is capable of exhibiting adult response patterns. However, there is evidence that the adult brain may regress to an infantile state when it is confronted with severe stress.

This 'infantile state' is a disorganised-disoriented state of insecure attachment. As in infancy, children, adolescents, and adults with posttraumatic stress disorders can not generate an active coherent behavioural coping strategy to confront subjectively perceived overwhelming, dysregulating events, and thus they quickly access the passive survival strategy of disengagement and dissociation.

Indeed, the type 'D' attachment classification has been observed to utilise dissociative behaviours in later stages of life [218], and to be implicated in the aetiology of the dissociative disorders [91]. The characterological use of dissociation over developmental stages is discussed by Allen and Coyne:

> Although initially they may have used dissociation to cope with traumatic events, they subsequently dissociate

> to defend against a broad range of daily stressors, including their own posttraumatic symptoms, pervasively undermining the continuity of their experience [219, p.620].

These 'initial traumatic events' are embedded in the abuse and neglect experienced by type 'D' infants, the first relational context in which dissociation is used to autoregulate massive stress. In developmental research Sroufe and his colleagues conclude that early trauma more so than later trauma has a greater impact on the development of dissociative behaviours [220]. Dissociation is a common symptom in PTSD patients, and its occurrence at the time of a trauma is a strong predictor of this disorder [221,222].

The fact that dissociation becomes a trait in posttraumatic stress disorders has devastating effects on self, and therefore psychobiological functions. In neurological studies of trauma Scaer refers to somatic dissociation, and concludes, 'Perhaps the least appreciated manifestations of dissociation in trauma are in the area of perceptual alterations and somatic symptoms' [223]. He further points out that distortion of proprioceptive awareness of the trauma patient's body is a most common dissociative phenomenon. Similarly, in clinical psychiatric studies Nijenhuis [224] is now describing not just psychological (e.g. amnesia) but 'somatoform dissociation', which is associated with early onset traumatisation, often involving physical abuse and threat to life by another person. Somatoform dissociation is expressed as a lack of integration of sensorimotor experiences, reactions, and functions of the individual and his/her self-representation.

This shift from the cognitive to the affective-somatic aspects of dissociation is echoed in the current neuroscience literature, which describes 'a dissociation between the emotional evaluation of an event and the physiological reaction to that event, with the process being dependent on intact right hemisphere function' [225, p.643]. Posttraumatic stress disorders therefore reflect a severe dysfunction of the right brain's vertically organised systems that perform attachment, affect regulating, and stress modulating functions, which in turn impair the capacity to maintain a coherent, continuous, and unified sense of self. Although the right brain's growth spurt is maximal in the first 2 years, it continues to enter into cycles of experience-dependent growth [226] and forms connections with the later developing left, which would be impacted by later relational trauma such as sexual abuse in childhood [227]. It is now thought that the effectiveness of newly formed and pruned networks in these later stages is limited by the adequacy of already-formed, underlying networks, and therefore maturation is optimal only if the preceding stages were installed optimally [228].

Traumatic attachment experiences negatively impact the early organisation of the right brain, and thereby produce deficits in its adaptive functions of emotionally understanding and reacting to bodily and environmental stimuli, identifying a corporeal image of self and its relation to the environment, distinguishing the self from the other, and generating self-awareness [14,47,98,229]. Optimal attachment experiences allow for the emergence of self-awareness, the ability to sense, attend to, and reflect upon the dynamic changes of one's subjective self states, but traumatic attachments in childhood lead to self-modulation of painful affect by directing attention away from internal emotional states.

From a psychoneurobiological perspective, dissociation reflects the inability of the right brain cortical-subcortical system to recognise and coprocess (integrate) external stimuli (exteroceptive information coming from the environment) and internal stimuli (interoceptive information from the body, the corporeal self). According to van der Kolk and McFarlane [230] a central feature of PTSD is a loss of the ability to physiologically modulate stress responses which leads to a reduced capacity to utilise bodily signals as guides to action, and this alteration of psychological defence mechanisms is associated with an impairment of personal identity.

These deficits are the expression of a malfunctioning orbitofrontal cortical-subcortical system, the senior executive of the right brain [14,18,29,31,45,56]. In light of the finding that the orbitofrontal cortex is involved in critical human functions that are crucial in defining the 'personality' of an individual [231], personaliity organizations that characterologically access dissociation can be described as possessing an inefficient orbital frontolimbic regulatory system and a developmentally immature coping mechanism. and because adequate limbic function is required to allow the brain to adapt to a rapidly changing environment and organise new learning [106], a metabolically altered orbitofrontal system would interfere with ongoing social emotional development. Early failures in attachment thus skew the developmental trajectory of the right brain over the rest of the life span, thereby engendering what Bowlby described as a diverting of development from its adaptive course, and precluding what Janet called an 'enlargement' of personality development.

De-evolution of right brain limbic circuits and PTSD pathogenesis

According to Krystal [232], the long-term effect of infantile psychic trauma is the arrest of affect

development. Because emotions involve rapid nonconscious appraisals of events that are important to the individual [233] and represent reactions to fundamental relational meanings that have adaptive significance [234], this enduring developmental impairment is expressed in a variety of critical dysfunctions of the right brain. PTSD patients, especially when stressed, show severe deficits in the preattentive reception and expression of facially expressed emotion, the processing of somatic information, the communication of emotional states, the maintaining of interactions with the social environment, the use of higher level more efficient defences, the capacity to access an empathic stance and a reflective function, and the psychobiological ability to regulate, either by autoregulation or interactive regulation, and thereby recover from stressful affective states. Most of these dysfunctions represent pathological alterations of early acting, rapid, implicit, unconscious mechanisms. Note that they also describe the deficits of borderline personality disorders, a condition that correlates highly with PTSD and shares both a history of early attachment trauma and orbitofrontal and amygdala dysfunction (see [44]).

Furthermore, the observations that in human infancy, the right brain, the neurobiological locus of the stress response, organises in an affective experience-dependent fashion, and that the emotion-processing and stress-coping limbic system evolves in stages, from the amygdala, to anterior cingulate, to orbitofrontal cortex [14,18], supports the concept of de-evolution as a mechanism of symptom generation in PTSD. Wang, Wilson, and Mason [235] describe 'stages of decompensation' in chronic PTSD, reflected in incremental impairments in amplified hyperarousal symptoms and defensive dissociation, decreased range of spontaneity and facial expression, heightened dysregulation of self esteem, deepening loss of contact with the environment, reduced attachment and insight, and increased probability of destruction and suicide. Intriguingly, they posit the existence of specifically three stages beneath a level of good to maximum functioning, and suggest each stage is physiologically distinct.

The concept of 'decompensation' describes a condition in which a system is rapidly disorganising over a period of time. This construct derives from Hughling Jackson's [236] classic principle that pathology involves a 'dissolution', a loss of inhibitory capacities of the most recently evolved layers of the nervous system that support higher functions (negative symptoms), as well as the release of lower, more automatic functions (positive symptoms). This principle applies to the dissolution of the vertical organisation of the right brain, dominant for inhibitory control [67], and the disorganisation of the complex circuit of emotion regulation of orbital frontal cortex, anterior cingulate, and amygdala [18,45,237]. and so it is tempting to speculate that the stage model of Wang and her colleagues describes a Jacksonian de-evolution of the 'rostral limbic system' [112], in reverse developmental order, from orbitofrontal loss, to anterior cingulate loss, and finally to amygdala dysfunction. At a certain threshold of stress, the frontolimbic systems of PTSD patients would be unable to perform a higher regulatory function over lower levels, thereby releasing lower level right amygdala activity, without the adaptive capacity of flexibly re-initiating higher control functions.

In addition, in light of the fact that the orbitofrontal, anterior cingulate, and amygdala systems each connect into the ANS [18], the mechanism of de-evolution dynamics would also apply to the hierarchical disorganisation of the autonomic nervous system. This would be manifest in long-lasting episodes of a coupled nonreciprocal mode of autonomic control, in which concurrent increases (or decreases) occur in both sympathetic and parasympathetic components, or uncoupled nonreciprocal mode of autonomic control, in which responses in one division of the ANS occur in absence of change in the other. In other words, the ANS would too easily be displaced from a state of autonomic balance, and once displaced, have difficulty in re-establishing balance, that is, show a poor capacity for vagal rebound and recovery from psychological stress [238].

This de-evolution would also be manifest in a stress-associated shift down from the higher ventral vagal complex (which is known to be defective in posttraumatic stress disorder [239]) to the dorsal vagal complex that mediates severe emotional states of terror, immobilisation, and dissociation. Ultimately higher vagal functions would be metabolically compromised, and dorsal vagal activity would predominate even in a resting state. This lowest level may be seen in infants raised in a neglectful environment [176], chronic PTSD patients with low cortisol levels [240,241], suicidal patients with severe right brain deficiencies experiencing intense despair [94], and Wang, Wilson, and Mason's [235] final stage of depression-hopelessness. This conception therefore suggests qualitative physiological as well as symptomatic differences between acute and chronic PTSD populations, and it relates developmental models of early organisation to later clinical models of disorganisation.

The ultimate endpoint of chronically experiencing catastrophic states of relational-induced trauma in early life is a progressive impairment of the ability to adjust, take defensive action, or act on one's own behalf, and a blocking of the capacity to register affect and pain, all critical to survival. Ultimately these individuals perceive

themselves as different from other people and outside of, as well as unworthy of, meaningful attachments [242]. Henry echoes this conclusion:

> The ability to maintain personally relevant bonds is vital for our evolutionary survival. The infant's tie to the mother's voice and odour is recognized even by the newborn [243], yet this personal relevance and recognition of the familiar can be impaired by anxious insecurity resulting from difficult early experiences or traumatic stress. The vital task of establishing a personally relevant universe and the solace derived from it depend on right hemispheric functioning. If this function is indeed lost in the insecurely attached, much has been lost (cited in [32]).

These survival limitations may negatively impact not just 'psychological' but essential organismic functions in coping with physical disease. Very recent studies are linking attachment, stress, and disease [244] and childhood attachment and adult cardiovascular and cortisol function [245], as well as documenting effects of childhood abuse on multiple risk factors for several of the leading causes of death in adults [246].

This developmental neurobiological model has significant implications for psychiatry and the other mental health professions. The organisation of the brain's essential coping mechanisms occurs in critical periods of infancy. The construct of critical periods implies that certain detrimental early influences lead to particular irreversible or only partially reversible enduring effects. But the flip side of the critical period concept emphasises the extraordinary sensitivity of developing dynamic systems to their environment, and asserts that these systems are most plastic in these periods. The development of the right brain is experience-dependent, and this experience is embedded in the attachment relationship between caregiver and infant.

Attachment researchers in association with infant mental health workers are now devising interventions that effectively alter the affect-communicating capacities of mother-infant systems, and thereby the attachment experiences of high risk dyads. Early interventions that are timed to critical periods of development of the right brain, the locus of the human stress response, can facilitate the maturation of neurobiologically adaptive stress coping systems, and thereby have lifelong effects on the adaptive capacities of a developing self. Early treatment and prevention programs, if expanded onto a societal scale, could significantly diminish the number of individuals who develop pathological reactions of mind and body to catastrophic life events. These efforts could, in turn, make deep inroads into not only altering the intergenerational transmission of posttraumatic stress disorders but improving the quality of many lives throughout all stages of human development.

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