Smith College Studies in Social Work, 84:292–309, 2014

ISSN: 0037-7317 print/1553-0426 online
DOI: 10.1080/00377317.2014.924251

Routledge
Taylor & Francis Group

Trauma's Neurobiological Toll: Implications for Clinical Work With Children

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Traumatic stress in childhood exacts a particularly high developmental toll. When traumatic experiences start early, continue chronically, and/or occur in conjunction with inadequate caretaking, neurobiological consequences intensify. Implicated brain regions include those mediating stress reactions, emotional arousal and regulation, attention, inhibition, impulse control, and various types of memory. To address those issues psychotherapeutically, treatment must comprehensively target underdeveloped or damaged neural networks. This article reviews current knowledge of the neurobiological and developmental affronts caused by traumatic stress during childhood and examines the various treatments and treatment implications for psychotherapeutic work with children.

KEYWORDS trauma, traumatic stress, child development, attachment, neurobiology

INTRODUCTION

Severe and prolonged traumatic stress, experienced in childhood, often exacts a developmental toll. Trauma disrupts neurobiological maturation by provoking alterations in emotional, behavioral, interpersonal, cognitive, sensory, and biological areas of functioning (Ford, 2009). When traumatic experiences occur in conjunction with inadequate caretaking, so that the attachment figure either serves as the source of fear and/or cannot help the child cope, the disruptive, dysregulating effects increase exponentially

Received 2 May 2014; accepted 2 May 2014.
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(Lieberman & van Horn, 2008; Lyons-Ruth, 2003; Streeck-Fischer & van der Kolk, 2000). Recent research on child development, attachment, and trauma has begun to explain when and how neurobiological domains optimally evolve and the damage they can sustain. This knowledge, in turn, is beginning to generate more refined and innovative treatments for traumatized children. However, though solid documentation now exists for children's typical and overt traumatic symptoms, as well as some of the associated and affected brain regions and neural pathways, the precise mapping of the underlying areas and understanding of causal mechanisms responsible for those symptoms remains rudimentary (H. Hart & Rubia, 2012; McCrory, DeBrito, & Viding, 2010). Open questions that continue to limit precise and targeted treatments include a better understanding of psychological change mechanisms, how the staging of interventions can best capitalize on the brain's variable plasticity, and to what extent treatment should seek to remediate or to compensate for developmental and structural damage (Cicchetti, 2013; Ford, 2009; McCrory et al., 2010; Perry, 2009; Zilberstein, 2014a). This article reviews current knowledge of the neurobiological and developmental affronts caused by adversity and maltreatment at vulnerable points in childhood and examines the various treatments and treatment implications of emerging research that guides psychotherapeutic work with children.

NEUROBIOLOGY OF CHILD DEVELOPMENT

Developmental neurobiology in part explains children's susceptibility to ongoing difficulties following chronic or severe trauma. Children's brains develop rapidly during the first 3 years of life and undergo a relatively long period of maturation. Growing in a bottom-up fashion, the lower brain matures first, with the most primitive structures already well developed by birth. Those primarily include the brain stem and midbrain, which govern autonomic, bodily functions such as respiration, digestion, and some types of visual and motor control. Postnatally, the brain continues to grow and organize as a function of age and experience. Various neurohormonal, neurotransmitter, and neuromodulator signals, which also originate in the lower brain, orchestrate this growth (Cozolino, 2002; Perry, 2009). They help form increasingly efficient pathways and communication between brain regions, especially when activated by repeated use. However, when faced with adversity, the brain favors development of some areas over others, at the expense of overall fluidity. For instance, stress causes the body to release the hormone cortisol, which provides the adrenaline rush needed to react quickly to threat. However, prolonged or frequent cortisol secretion, which occurs during chronic trauma or ongoing attachment difficulties, sensitizes and conditions the body to stress, thus contributing to recurrent and easily induced

episodes of physiological and emotional dysregulation (Ford, 2009; Gunnar & Quevedo, 2007). Once established, such neurologically wired patterns of reactivity can become hard to change, particularly if they begin early in life and affect the development of other neural pathways and brain regions.

During the first few years of life, rapid growth and synchronization occurs in three primary brain areas: the limbic system, which processes emotions, coordinates self-regulation and the formation of memories; the cortical areas, which coordinate the cognitive and executive functions; and the stress response system (S. Hart, 2011; Schore, 2001). Cortical areas, such as the prefrontal cortex that mediates complex thought, executive functions, and inhibitory control over emotions take longest to develop. They do not reach full potential until early adulthood. This long interval of growth renders children's brains particularly vulnerable and sensitive to environmental factors, for better and for worse (Thompson-Schill, Ramscar, & Chrysikous, 2009). A less advanced prefrontal cortex allows youth to explore flexibly, learn rapidly, think creatively, and adapt to their surroundings (Thompson-Schill et al., 2009). However, it also reduces children's behavioral and cognitive control, making them especially at risk when their milieu does not monitor or protect them or promote optimal learning.

As is discussed further below, experiences of traumatic stress and inadequate caretaking in the early and formative years can interrupt the development of each of those brain structures in detrimental ways. The type of damage that transpires depends in part on that child's previous development and genetic make-up (Goslin, Stover, Berkowitz, & Marans, 2013). The child's age also has a tremendous effect as it determines which parts of the brain and nervous system are developing most quickly and so most likely to be thrown off course (Herringa et al., 2013; Salmon & Bryant, 2002). Because experience partly shapes and organizes the brain, especially relational and attachment experiences, earlier, more severe, and more persistent traumatic occurrences and attachment difficulties lead to more negative, enduring, and extensive consequences (Beers & DeBellis, 2002; Chae, Ogle, & Goodman, 2009; Cozolino, 2002; Streeck-Fischer & van der Kolk, 2000). This is in part because when lower brain regions and neurotransmitter systems develop suboptimally, they hamper growth of the higher, cortical regions and of efficient communication between various brain regions (Perry, 2009). This has far-reaching consequences for how children learn to regulate and attend to sensory, emotional, and social stimuli as well as for the consolidation of memory and the ability to understand and make meaning of experiences.

ATTACHMENT'S CONTRIBUTION TO CHILDREN'S OUTCOMES

The strongest predictor of psychological health and resiliency remains the quality of interpersonal relationships, particularly attachment relationships

(Bowlby, 1982; Siegel, 1999). A caregiver's attunement and sensitivity to the young child's state and reflection of that emotional understanding appear crucial to attachment and to development, in general (Ainsworth, Blehar, Waters, & Wall, 1978; Bowlby, 1982; S. Hart, 2011). Available and attuned attachment figures serve as secure bases that encourage exploration, learning, and multiple other developmental achievements (Ainsworth et al., 1978; S. Hart, 2011; Siegel, 1999). Studies of parents and infants playing together elucidate the interactive dance in which the dyad's movements and expressions become synchronized in microsecond responses (Beebe & Lachman, 2003). Early attachment patterns consolidate through these sensorimotor and emotional communications that include voice tone, touch, gestures, and vocalizations (Beebe & Lachmann, 2003; Bowlby, 1982; S. Hart, 2011). Through these experiences, children also form schemas, or internal working models, of the self, others, and relationships that help guide their behavior in times of danger or need (Bowlby, 1982).

Below the surface, these interpersonal exchanges correlate with important neurological developments. The infant's nervous system literally organizes itself through these microinteractions (S. Hart, 2011). During the same developmental period in which attachments become established and consolidated into working models, that is, during the first 3 years of life, the limbic, cortical, and stress response systems are simultaneously developing (Gunnar & Quevedo, 2007; S. Hart, 2011; Schore, 2001). Those regions govern physical arousal, regulation, and social affiliation, areas particularly affected and shaped by attachment experiences. When an infant imitates the movements, countenance, and sounds of the caregiver, that child learns to connect bodily sensations with feelings, words, and the emotional states of others, thus building important synaptic connections in regions of the brain associated with language, emotions, and sociability (Hart, 2011). As a consequence, infants of responsive and sensitive mothers show more activity in left frontal brain areas that coordinate positive emotion and affiliation (Gunnar & Quevedo, 2007; Schore, 2001).

Through those interactions, emotional and physical regulation also consolidates (Fonagy, Gergely, Jurist, & Target, 2002; S. Hart, 2011; Schore, 2001). Attuned caretakers regulate and keep tolerable a child's arousal and encourage that child to use them to soothe distress in times of need, thus further reducing anxiety. As a consequence of multiple, successful experiences of managing mild disturbances, the child's limbic and cortical regions mature and become better and better at bearing and coping with stress (Ford, 2009). Language also helps this process. Skillful attachment figures encourage reflection and discussion of emotional material, thus building understanding, toleration and regulation of mental and emotional states (Cozolino, 2002; Fonagy et al., 2002; S. Hart, 2011; Hughes, 2004; Siegel, 1999). Supportive care and secure attachments thus establish important neurologically based buffers that help children withstand future stressful events.

By the end of the first year of life, securely attached infants display resiliency, in part because of their strengthened stress response and cortical systems (Gunnar & Quevedo, 2007; Hane & Fox, 2006; S. Hart, 2011). Although negatively affected by traumatic experiences, their more advanced regulatory skills, more sophisticated coping mechanisms, and comfortable dependence on caregivers who cushion the effects of stress allow them to manage more tenaciously when faced with adversity.

On the other hand, children without secure attachments exhibit various difficulties coping with disturbing thoughts, feelings, and experiences. Whether they reveal it overtly, insecurely attached children show biological markers of apprehension when desiring care and comforting. Their heart rates and cortisol levels rise (Gunnar & Quevedo, 2007). Securely attached infants show no such elevation in cortisol levels when crying to get their parents' attention. Children with insecure and disorganized attachments also display more difficulty recognizing, regulating, and integrating various cognitive and emotional cues. Self-reflection and problem solving remain less developed as the child's attempts to cope with dsyregulation leave little space for concentrating on, utilizing, and developing higher order cortical regions and skills (Fonagy et al., 2002; Ford, 2009; S. Hart, 2011). This leaves them especially vulnerable to trauma and stress.

NEUROBIOLOGICAL EFFECTS OF TRAUMA

Trauma constitutes one of the most stressful and taxing experiences children may encounter. A number of studies have now looked at its neurobiological and long-term effects. They suggest that childhood maltreatment and adverse experiences trigger cascading physiological, hormonal, and neurochemical changes that alter brain structures and functions (Beers & DeBellis, 2002; H. Hart & Rubia, 2012; McCrory et al., 2010; Perry & Pollard, 1998). Although the results of these studies must be viewed with caution due to their small sample sizes, populations spread heterogeneously across different traumatic experiences, lack of consistent measures of maltreatment severity, limited studies on children, and difficulties separating the effects of maltreatment from psychopathology, some fairly consistent and robust findings have emerged (H. Hart & Rubia, 2012; McCrory et al., 2010). Altered or diminished structures and systems include the hypothalamic-pituitary-adrenal axis (HPA) or the stress response system, reduced volume in the corpus callosum and cerebellum, and reduced activity and functioning in certain localities of the prefrontal cortex, limbic, and paralimbic systems. Those implicated brain regions influence stress reactions, emotional arousal and regulation, attention, inhibition, impulse control, and various types of memory. Although some of those areas overlap with and perhaps exacerbate problems in children experiencing insufficient attachments—that is, the stress response and

regulatory systems—others, having to do with attention, inhibition, impulse control, and memory are unique. These deficits then have far reaching influence on children's overall functioning.

Trauma affects children so severely in part because it interrupts and overwhelms developing neural pathways with stimuli and experiences that the brain is not yet equipped to manage. Before language and symbolic representation fully form, the brain encodes memories implicitly and does not integrate them with verbal centers, so that consciously remembering and making sense of traumatic experience—even later in life—becomes difficult (Salmon & Bryant, 2002; Streeck-Fischer & van der Kolk, 2000). With little prior knowledge upon which to understand experiences, young children also process new occurrences more slowly and with less detail (Perry & Pollard, 1998; Salmon & Bryant, 2002). This fragments memory, making it less available for appraisal or integration. In addition, because of the highly arousing and emotional nature of traumatic experience, the child's nascent stress response system and coping abilities become compromised and overwhelmed, leading to dysregulation on biological, emotional, and behavioral levels and further complicating efforts to remember or derive meaning out of what happened.

Trauma interferes with neurobiological domains in other ways, as well. Traumatic experiences stimulate a heightened fear response in the limbic areas of the amygdala and hippocampus and selective attention to those parts of the experience necessary for survival. This overexcites the amygdala, which mediates memory for emotional events, and weakens the hippocampus, which consolidates short-term into long-term memory (S. Hart, 2011; Herringa et al., 2013). As a consequence, individuals experience high arousal and diminished processing and integration of memories. Sensory, emotional, and cognitive reactions become dissociated so that the child can neither evaluate nor curtail the associated fear and arousal (Cozolino, 2002). In addition, because the trauma and later traumatic triggers command attention, the child directs less attention to other stimuli, at the expense of broad learning (Ford, 2009; Perry & Pollard, 1998). When such demands are made repeatedly during developmentally sensitive times, the child's emerging biology and brain become structured around hypervigilance and safety seeking (Perry & Pollard, 1998; Streeck-Fischer & van der Kolk, 2000). This conditions the child to become overly attentive and reactive to stress, as the child's stress system responds more and more quickly and efficiently to smaller and smaller stresses, thus contributing to the child's general behavioral and emotional dysregulation (Ford, 2009; Gunnar & Quevedo, 2007). The ensuing hyperarousal and misinterpretation of threat and fear further impels the child to miscue to social and other situations, contributing to problems in multiple domains (Cozolino, 2002; Zilberstein, 2014a). These states of hyperarousal, fragmentation, and restricted attention and learning then establish a weaker foundation for navigating subsequent developmental challenges.

Variations in Traumatic Stress Responses

Although chronic, adverse experiences and traumatic experiences tend to afflict specific neural regions, there remains much variation in individuals' reactions. Many factors affect a child's ability to tolerate stress. These include prior history of trauma, whether parenting has been supportive or hostile, and other genetic or learned competencies and skills (Goslin et al., 2013; Lieberman & van Horn, 2008). Temperament and inborn stress reactivity also leave an imprint (Phillips, Fox, & Gunnar, 2011). So may innate cognitive ability, though it is often hard to separate out environmental factors that decrease cognitive functioning and IQ from genetic potential (Beckett et al., 2006; Saltzman, Weems, & Carrion, 2006; Shonk & Cicchetti, 2001). Each of these pre-event factors serves either to mitigate or exacerbate a child's response and recovery and is important to understand as part of the contextual landscape that affects treatment.

Factors following traumatic exposure also influence children's adjustments. As children strive to cope with or compensate for early deficiencies, they continue to develop adaptively and maladaptively in various cognitive, emotional, and relational domains (Gerber, 2006; Sroufe, Carlson, Levy, & Egeland, 1999). New relational experiences as well as growing cognitive and self-regulatory abilities can help children gain new skills and resources that aid recovery (Raikes & Thompson, 2005). Dysregulation combined with attentional and cognitive difficulties can also lead to cascading problems such as poor peer relationships or school performance that add additional stresses (Cozolino, 2002; Zilberstein, 2014a). A child may also develop certain defensive strategies, such as avoidance, so as not to feel the intense pain, fear, and dysregulation engendered by those experiences. In addition, many other developmental and environmental factors (such as family, race, culture, and poverty) mix together to determine a child's relative response. Children's responses to trauma can thus be flexible and durable, both modified by and shaping of subsequent experiences.

RIGIDITY AND PLASTICITY IN DEVELOPMENT

Neural mechanisms and their associated patterns of thinking, feeling, and behaving sometimes rigidly persist. They influence perceptions of and reactions to future events, thus strengthening and confirming preexisting pathways, ideas, and responses (Cozolino, 2002). Studies indicate that this can occur in response to both attachment and traumatic triggers. Working models of attachment influence memory for attachment-related experiences so that insecure children recall more negative events and rejecting parental responses than securely attached children, even when given the same attachment-related scenarios (Chae et al., 2009; Rowe & Carnelley,

2003). Avoidantly attached children and adults also show less accuracy in recounting distressing or traumatic experiences, partly because they exclude and so do not reflect upon or encode information that might activate their attachment systems (Chae et al., 2009). This means that without focusing those individuals on various types of omitted and overlooked information, they are not likely to notice, process, or remember them, thus perpetuating their perceptions and belief systems.

Despite such rigidity, the brain also remains plastic throughout life. Ingrained biological, emotional, and behavioral patterns can and do change in response to new experiences and stimuli (S. Hart, 2011; Perry, 2009). In fact, the brain and nervous systems' malleability, which make them so vulnerable to damage, also render them receptive to reparation and growth. Growing evidence suggests that the children who show the most susceptibility to adverse events are also the most amenable to positive experiences (Belsky & Pluess, 2009). Highly reactive children and those with difficult temperaments develop more poorly than others when experiencing inadequate parenting but outperform peers when parenting is skillful (Belsky & Pluess, 2009). Although it is not clear whether the damage caused by severe trauma diminishes that pliability, it does suggest that some of the children most hurt by maltreatment may also retain significant ability to adjust positively when circumstances improve.

TREATMENT

An understanding of the neurobiological processes underlying childhood trauma lends itself to a few important principles when formulating treatments. First of all, individual variation in how children respond to adversity and stress depends, in part, on their unique genetics, biology, and circumstances and means that comprehensive assessments are needed (Ford, 2009; Zilberstein, 2014a). Second, research on child development, resiliency, and plasticity particularly highlight the role of caregiving in promoting positive or negative outcomes and neurological change (Cicchetti & Gunnar, 2008; Hane & Fox, 2006). Treatment of traumatized children cannot be conducted independently of the caregiving and relational environments in which they function. Third, reversing the accumulated wear and tear of traumatic experiences and insufficiently protective attachment relationships requires interventions that appropriately target underdeveloped or damaged brain regions, particularly in the areas most affected by trauma: sensory integration, self-regulatory ability, relationships, cognitive and executive functioning, and memory. To change neural networks, treatment must first activate those systems (S. Hart, 2011; Perry, 2009), though the best ways to do so remain an open question. Last, developmental considerations are important as the timing and aiming of an intervention can enhance its effectiveness. Just as

the brain and nervous system endures more damage during periods of rapid brain development, those phases also provide opportunities for heightened plasticity and growth (Cicchetti & Gunnar, 2008; Herringa et al., 2013; Perry, 2009).

Comprehensive Assessment

Children vary in their response to trauma based on their genetics, temperament, history, security of attachment, the age at which the trauma occurred, and its duration and severity. A child whose immature neural systems become dysregulated by trauma before they have organized and developed will sustain more damage than children traumatized later in life (Beers & DeBellis, 2002; Chae et al., 2009; Streeck-Fischer & van der Kolk, 2000). In addition, the effects of trauma on a child or family cannot be separated from other risk or protective factors that affect that child. A variety of cultural, familial, and contextual factors affect children's responses. Other stressors, such as poverty, racism, and parental depression or supportive factors such as a caring network of adults, peers, and community also shape the child and development. Last, as development progresses, efforts to cope or compensate with the trauma and the damage it creates may adaptively or maladaptively affect the child. Those factors cannot be considered simply as accessories to the primary treatment of trauma but, in fact, mold a child's symptoms in unique and important ways that must be addressed conjointly (Zilberstein, 2014b). In this regard, assessment must broadly assess a wide spectrum of developmental, relational, and contextual factors so that interventions can be appropriately tailored to the unique needs and circumstances of each child and family (Ford, 2009; Perry, 2009). However, given what is known about the typical and most enduring neurodevelopmental impact of trauma, relational capacity and emotional dysregulation must be considered crucial concerns and considered in depth. If interventions do not target those needs, not only will they be ineffective, they could make emotional demands that exceed a person's ability to cope and thus create additional harm (Ford, 2009; Perry, 2009).

Role of Relationships and Attachments

Treatment of trauma must enhance attachment relationships. This entails helping caregivers learn to attune to and sensitively parent the child and aiding children in accurately cueing attachment needs and using relationships for support (Blaustein & Kinniburgh, 2010; Hughes, 2004; Lieberman & van Horn, 2008; Zilberstein, 2014b). Attachment-based treatments generally achieve these goals by working together with parents and children to challenge existing internal working models, develop affect regulation and

reflective functioning, and repair empathic breaks through attuned responses (Berlin, Ziv, Amaya-Jackson, & Greenberg, 2005; Hughes, 2004; Lieberman & van Horn, 2008). Parents learn to reflect upon their own and their child's feelings and behavior and to match the child's affect through verbal and nonverbal means, thereby increasing positive and effective responses to that child. Most current attachment-based treatments target younger children who appear to derive the most benefit from those interventions (Berlin et al., 2005; Lieberman & van Horn, 2008; Zilberstein, 2014b). This may be partly due to the fact that children's limbic systems are growing rapidly and are most plastic in the early years, making them more open to attachment-based and regulatory learning (Perry, 2009; Schore, 2001). Young children also depend more upon attachment figures than do older individuals, encounter fewer external influences, and exhibit less rigidly formed working models, all of which boost the likelihood of successful attachment-based treatment (Zilberstein, 2014b).

As children age, their dependence on attachments shifts, yet continued attention to the caregiving environment remains important. Although other relationships, experiences, and capabilities also influence the older child, attachment figures continue to guide and affect children, even in adolescence (Allen, 2008; Raikes & Thompson, 2005). In addition, as is discussed further, children with cognitive and regulatory deficits secondary to trauma often require many repetitions of new skills to modify and reorganize the affected neural networks (Perry, 2009). Such children commonly have difficulty independently generalizing or practicing therapeutic gains in daily life. They thus show increased benefit when caregivers learn to structure the home environment in certain ways and provide opportunities to practice relational and regulatory skills (Blaustein & Kinniburgh, 2010; Hughes, 2004; Lieberman & van Horn, 2008). When a caregiver is not available or ready to provide those arrangements, the therapist may need to consider whether other milieus in which the child functions, such as schools, can provide the necessary adjunctive experiences (Perry, 2009; Warner, Koomar, Lary, & Cook, 2013).

Not just caregivers, but therapists can also provide important, curative attachment relationships. Research consistently shows that the quality of the therapeutic relationship has a strong influence on the outcome of therapy (Norcross & Wampold, 2011). Knowledge of the neurobiology of attachment can thus assist the clinician in adopting relational stances and behaviors most likely to promote change. This involves attention to those aspects of the therapeutic relationship that foster secure attachments: safety and boundaries, attunement, responsiveness, reflective functioning, verbal and nonverbal emotional communication, and repair of empathic breaks (Bowlby, 1982; Cozolino, 2002; Fonagy et al., 2002; S. Hart, 2011; Hughes, 2004).

Activation of Neural Networks

Neurobiological change occurs as a function of experience. Novel stimuli and learning opportunities engineer new connections between different brain regions that then communicate more rapidly and efficiently the more they are exercised (Cozolino, 2002; Perry, 2009; Siegel, 1999). Because the brain initially develops in a bottom-up fashion, with the lower regions helping to organize the higher ones, some clinicians suggest that treatment should replicate that sequence (Perry, 2009; Warner, Cook, Westcott, & Koomar, 2011). A few studies support this approach (Barfield, Dobson, Gaskill, & Perry, 2012; Warner et al., 2013). "Bottom-up" tactics first target somatosensory self-regulation through repeated rhythmic activities (dance, drumming, rocking, and other types of movement), then relational skills, followed by verbal and insight-oriented work. Because those lower-level brain realms show less plasticity than higher-level cognitive domains, Perry (2009) notes that altering them requires more patterned, frequent, and predictable enrichment opportunities.

It is not yet clear how these sensory interventions differ or compare to more common types of age-appropriate physical training and activities that could be used in combination with other trauma and relational treatments. Research on nontraumatized populations robustly indicates that exercise and movement, in general, decrease anxiety and increase resilience to stress (Schoenfeld, Rada, Pierunzzini, Hsueh, & Gould, 2013). Taken together, however, these theories and associated studies suggest, at the very least, an important role for structured physical and sensory activity in promoting regulatory ability in traumatized children.

Activating and regulating the lower brain regions appears to improve self-control and decrease emotional responses, thus creating a necessary platform for other types of growth. But it likely does not, in itself, remediate the many other difficulties that often accompany experiences of trauma. Research suggests, for instance, that although secure attachments formed in early childhood help inoculate children from numerous later difficulties, many of the behavioral, social, cognitive, and emotional difficulties that poor attachments and adverse experiences engender can persist even after secure attachments are eventually formed (Beckett et al., 2006; Colvert et al., 2008). Therapy must thus also specifically stimulate the neural networks governing those other processes, as well.

Traumatized children often need help acquiring coping skills, gaining social competence, and learning to attend to, think about, and process sensory, emotional, and interpersonal cues rather than allowing their stress response systems to react automatically (Blaustein & Kinniburgh, 2010; Ford, 2009). Those abilities will not necessarily develop without the therapist drawing the child's attention to them and helping her or him to reflect upon and practice the associated skills. Some of this work may take on a structured,

didactic component (Blaustein & Kinniburgh, 2010), whereas other aspects can occur through relational work or play therapy.

Therapies that involve expression of and reflection on feelings, motivations, and mental states and motivations, such as found in psychodynamic and play treatments, can also enhance overall regulatory ability and provide important activation of cortical regions (Cozolino, 2002; Fonagy et al., 2002; S. Hart, 2011; Hughes, 2004; Levy, 2011). Language and the representation of experience constitute powerful tools that allow for increased self-control over emotions and better integration of thoughts with feelings (Chae et al., 2009; Cozolino, 2002; Fonagy et al., 2002; Siegel, 1999). Interactive play also aids growth of the orbital frontal cortex, which coordinates social activities (Pellis & Pellis, 2007). Such methods provide important experiences for traumatized children, who, biologically primed to react to stress and danger, often misinterpret events as threatening and respond to them as such (Ford, 2009; Gunnar & Quevedo, 2007; Herringa et al., 2013). However, some children who show high levels of dysregulation and have little ability to engage in relationships or organize their internal worlds may find that psychodynamic and play treatments do not offer enough directed attention, structure, or scaffolding to build a wide range of necessary skills (Vanheule, Verhaeghe, & Desmet, 2010; Warner et al., 2013).

Like other neural networks, memories must also be activated if they are to be integrated or changed (Dorfman & Mandler, 1994). For children who have experienced prolonged and multiple traumatic experiences, or whose traumatic experiences occurred early in life, remembering and processing that trauma is a complex endeavor (Blaustein & Kinniburgh, 2010; Herringa et al., 2013; Salmon & Bryant, 2002). Sometimes distinct episodes of trauma exist while at other times it simply pervades the overall landscape of the child's experience. However, as trauma dissociates sensory and emotional experiences from cognitive appraisals and understandings, some attention must be given to helping children integrate and make meaning from those fragmented aspects of themselves. This involves directing attention to their sensory and emotional reactions, helping them understand why and how those reactions occurred, developing a cohesive narrative about the past, and creating new meanings upon which to proceed. Careful attention must be given to the potential dysregulating effects of this work, which must be paced, dosed, and accompanied by adequate building of coping and regulatory skills (Blaustein & Kinniburgh, 2010; Cohen, Mannarino, & Deblinger, 2006; Hughes, 2004).

Developmental Considerations

Research on the effects of trauma and early adversity makes clear that such experiences interrupt and compromise development in numerous areas. Clinicians must understand the various ways children are and are not on track

developmentally as well as the reasons for those discrepancies. Often development in traumatized children proceeds unevenly, with skills in some areas outpacing those in others. Children delayed or handicapped by traumatic experience generally show some natural improvements in developmental abilities as they age, even when their overall proficiency and repertoire of skills remain well below those of similarly age peers (Cicchetti, 2013). For instance, a school-age child might perform adequately in some cognitive or motor tasks, while functioning at a very young level socially and emotionally. Therapists need to understand how to meet those "younger" needs in ways that still recognize and honor the child's chronological age.

Just as the brain and nervous systems endure more damage when exposed to toxic environments during periods of rapid development, those times also provide opportunities for heightened plasticity and growth (Cicchetti & Gunnar, 2008). Interventions targeted to emerging skills during normative growth spurts are hypothesized to show increased efficacy. This means, for instance, that infants and young children will likely respond more quickly to somatosensory and physically nurturing activities than will adolescents (Perry, 2009). This also means that when nurturing and sensory activities are offered to older children, they must match the physical and cognitive capacities and interests of those ages rather than replicate activities geared toward younger children (Ford, 2009; Zilberstein, 2014b). As children mature, they also generally acquire more cognitive and regulatory proficiency, which affords them new tools for handling the dysregulating effects of trauma. Those include increased working memory, better logical thinking, improved emotional and behavioral regulation, the ability to plan and set goals, more advanced social understanding, and an ability to reflect on and monitor their own thoughts and behavior (Bumge & Wright, 2007; Raikes & Thompson, 2005; Salmon & Bryant, 2002). Adolescence, a time in which abstract representational understanding blossoms, may provide a prime opportunity for children to reappraise old beliefs and acquire new schemas of the self, others, relationships, and the world (Allen, 2008; Ford, 2009). Such gains allow for the introduction of some cognitive-behavioral techniques in the treatment of school-age and adolescent youth that can focus on conscious understanding and control of emotions, behavior, and social relatedness (Blaustein & Kinniburgh, 2010; Cohen, Mannarino, & Deblinger, 2006; Gruber, Hay, & Gross, 2014).

The variable availability of a child's budding skills and resources for therapeutic work suggests that remediation of defective or underdeveloped brain structures may not always need to follow a more normative, "bottom-up" developmental pathway. Although trauma disrupts and interrupts the acquisition of many skills, it does not necessarily derail them altogether or even uniformly (Cicchetti, 2013). Harnessing a child's particular strengths and areas of resiliency may, in fact, aid healing. Such a strategy resembles the treatment of children with learning disabilities, who also struggle with

neurodevelopmental deficits. Those remedies encompass numerous techniques that could be helpful with traumatized children: specific skill training, pairing strength in one domain with weakness in another, and the use of various compensatory strategies (Dehn, 2008; Greenspan & Wieder, 2006; Zilberstein, 2014a).

CONCLUSION

Understanding how childhood trauma afflicts various neural systems can aid clinicians in selecting and utilizing those interventions most likely to affect change. Although much remains unknown about the efficacies of different approaches for various subpopulations, consensus now exists on a number of broad principles. Most treatments for trauma rightly emphasize the need for children to be anchored in secure and nurturing relationships, and the primacy of that goal as a therapeutic target (Blaustein & Kinniburgh, 2010; Fonagy et al., 2002; Ford, 2009; Hughes, 2004; Lieberman & van Horn, 2008). After all, attachment constitutes the developmental foundation and tool upon which neurobiological self-regulation grows (Schore, 2001). Interventions must also focus on helping children gain or remedy insufficient developmental capacities and do so within the child's current context and utilizing that child's developmental aptitudes and strengths. Primary among these are the building of regulatory and reflective ability that allows for the development of a range of coping skills (Blaustein & Kinniburgh, 2010; Fonagy et al., 2002; Ford, 2009; Perry, 2009). Given that the brains of traumatized children organize around survival, safety, and detecting threat, which affects numerous neural systems, treatment must also activate many different brain regions to stimulate new learning (Cozolino, 2002; S. Hart, 2011; Ford, 2009; Perry & Pollard, 1998). This may entail the use of various interventions and change components that span sensory, attachment-based, relational, and cognitive approaches as well as didactic, skill-building exercises (Berlin et al., 2005; Blaustein & Kinniburgh, 2010; Cohen et al., 2006; Cozolino, 2002; Fonagy et al., 2002; Ford, 2009; Hughes, 2004; Lieberman & van Horn, 2008; Perry, 2009; Warner et al., 2012). Whether treatment must occur in a "bottom-up" or "top-down" fashion, however, remains unclear. More likely, interventions that engage multiple networks by combining both bottom-up and top-down interventions (depending on the needs and developmental age of the child) will increase integration of dissociated networks and enhance learning.

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