Changing Minds: Discussions in neuroscience, psychology and education

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Childhood trauma: Developmental pathways and implications for the classroom

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Changing minds: Discussions in neuroscience, psychology and education

The science of learning is an interdisciplinary field that is of great interest to educators who often want to understand the cognitive and physiological processes underpinning student development. Research from neuroscience, psychology and education often informs our ideas about the science of learning, or 'learning about learning'. However, while research in these three areas is often comprehensive, it's not always presented in a way that is easily comprehensible. There are many misconceptions about neuroscience, psychology and education research, which have been perpetuated through popular reporting by the media and other sources. These in turn have led to the development of ideas about learning and teaching that are not supported by research. That's why the Centre for Science of Learning @ ACER has launched the paper series, *Changing Minds: Discussions in neuroscience, psychology and education*.

The *Changing Minds* series addresses the need for accurate syntheses of research. The papers address a number of topical issues in education and discuss the latest relevant research findings from neuroscience, psychology and education. *Changing Minds* does not provide an exhaustive review of the research, but it does aim to provide brief syntheses of specific educational issues and highlight current or emerging paradigms for considering these issues across and within the three research fields. The paper series also provides teachers, school leaders and policymakers with accessible multidisciplinary theory and research that can be used to reflect on educational practice and policy.

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Background

New understandings in developmental and neuroscience research have challenged popular ideas about trauma exposure and brain development during childhood. There is a general misconception that children are more resilient than adults to the effects of trauma and will 'outgrow' traumatic experiences (Lieberman & Knorr, 2007). However, these ideas are incorrect and are not supported by current research.

In the classroom, children's trauma symptoms may be understood as attentional deficits, learning disabilities, or behavioural or conduct problems (Downey, 2007). Researchers like Teicher et al. (2003) argue that trauma-informed behaviours are important coping mechanisms that a child may develop to survive extremely stressful experiences, and that focusing on eliminating these behaviours may be damaging to a child, especially in the context of ongoing trauma. Therefore, it is important for educators working with traumatised children to understand the key developmental pathways that may be affected by childhood trauma, and to understand how to support resilience through these pathways (Perkins & Graham-Bermann, 2012).

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This paper provides a brief synthesis of relevant research from neuroscience, psychology and education to highlight new understandings in childhood trauma research. Rather than being an exhaustive review, it aims to highlight relevant research when considering childhood trauma, and to support reflection on current practice and policy when considering traumatised children in schools.

The paper has five main sections:

- An overview of childhood trauma – what it is and its associated outcomes.
- New understandings of childhood trauma that help researchers better understand the wide-ranging effects associated with trauma.
- Neuroscience research about the body and brain's stress-response systems.
- Psychological and educational research that explores the development of emotional and cognitive functioning after trauma exposure.
- Implications for practitioners based on current research.

Overview of childhood trauma

What is childhood trauma?

Childhood trauma is typically characterised by two principal criteria:

- the *experience,* which includes the type and duration of trauma experienced, and
- the child's *reaction* to trauma exposure, such that these experiences overwhelm a child's ability to cope and cause the child to feel extreme fear, helplessness or horror (American Psychological Association, 2008).

Traumatic experiences – usually classified as simple or complex trauma (Australian Childhood Foundation, 2010) – are events that threaten the physical integrity of the child or others close to them with harm, injury or death (American Psychological Association, 2008).

Simple trauma typically refers to discrete life-threatening events such as accidents, or natural or man-made disasters. Experiences may include illness or disease, car accidents, bushfires, floods, industrial accidents, war or terrorism.

Complex trauma involves repeated or ongoing threats of violation or violence between a child and another person. It may include experiences such as bullying; emotional, physical or sexual abuse; child maltreatment or neglect; or witnessing domestic violence. Complex trauma that disrupts the development of secure attachment to a parent or primary caregiver has the potential to have profound developmental consequences for a child (De Bellis, 2001), and is the most stressful trauma that a child can experience (Van Horn, 2011). Complex trauma can occur through the loss or death of a parent (Gregorowski & Seedat, 2013), or when the parent or caregiver is the primary perpetrator of trauma.

Studies that estimate the prevalence of childhood trauma, whether in Australia or more widely, show wide-ranging variability in the estimated exposure rates (Broadley, Goddard, & Tucci, 2014; Fairbank, 2008; Taylor et al., 2008). It is difficult to reliably estimate due to issues concerning measurement, definitional frameworks, ethics and privacy (Masten & Osofsky, 2010; Veltman & Browne, 2001), and because risk factors for trauma exposure may also vary by background characteristics such as gender or ethnicity (Hodges et al., 2013; Kilpatrick & Saunders, 1999).

Despite these limitations, researchers *do agree* that trauma exposure in childhood is widespread (American Psychological Association, 2008; Finkelhor, Turner, Shattuck, Hamby, & Kracke, 2015), and also unfortunately that it is a common experience once children reach adolescence and adulthood (Anda et al., 2006). Childhood trauma may often go unrecognised by larger society, as the interpersonal nature of complex trauma, such as physical, emotional and sexual abuse, may involve the experience of shame and stigma, and unfortunately, societal responses of blame or disbelief (Australian Childhood Foundation, 2010).

What long-term psychological and health outcomes are associated with trauma?

Research has traditionally used psychological and clinical lenses to understand the long-term outcomes associated with trauma (Yates, 2007). Children who experience trauma may show varying signs of short-term distress as they try to cope with the experience, for example, sadness, anger, anxiety, disengagement, poor concentration or sleep problems. In time, most children display resilience and return to normal functioning after traumatic experiences, particularly in simple trauma cases (van der Kolk, 2003). However, it is widely accepted that childhood trauma exposure may be related to longer-term developmental and life outcomes, and increased risk for poorer psychological, health and behavioural functioning among children and adults (Institute of Medicine of the National Academies, 2013).

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Considering long-term outcomes for children, research suggests that complex trauma is associated with an increased risk for developing internalising disorders, such as post-traumatic stress disorder (Alisic et al., 2014; McLaughlin et al., 2013), anxiety, and earlier onset and longer duration of depression (Cook et al., 2005). Complex trauma is also associated with an increased risk of co-occurring externalising disorders in children, such as autism, attention deficit hyperactivity disorder (ADHD), conduct disorder, oppositional defiant disorder, problem drug use, aggression, self-harm and suicide (Kilpatrick & Saunders, 1999; Perkins & Graham-Bermann, 2012; van der Kolk, 2003).

There is also a strong body of research in health epidemiology and neurobiology that has established a link between childhood traumatic experiences and a variety of health and behavioural outcomes in adulthood (Anda, Butchart, Felitti, & Brown, 2010). Cumulative, or increasing trauma exposure during childhood shows an increased risk for difficulties in adulthood, such as substance abuse and addiction, sexual dysfunction and partner violence, psychological and psychiatric disorders, affective or mood disorders, suicide, somatic or physical complaints, lung disease, heart disease, diabetes and obesity (Anda et al., 2006; Felitti, 2002; Gunnar & Quevedo, 2007).

What educational outcomes are associated with trauma?

Research in psychology and education suggests that trauma is associated with poorer education outcomes, and that traumatised children use more school and system-level academic supports, have lower academic achievement, and have higher rates of grade repetition and school drop-out (Duplechain, Reigner, & Packard, 2008; Perzow et al., 2013).

Consensus among researchers is that complex trauma exposure is associated with poorer 'global' cognitive and intellectual functioning (Hart & Rubia, 2012; Pechtel & Pizzagalli, 2011), although there is more research that examines this relationship in adult populations than with children (Beers & De Bellis, 2002). A systematic review that examined three decades of child maltreatment research found that 75 to 90 per cent of included studies reported evidence of delayed intellectual or language development, and poorer academic outcomes (Veltman & Browne, 2001), and some evidence suggests that the relationship between trauma exposure and impaired cognitive functioning may be observed across different types of trauma exposure (Cook et al., 2005).

Although researchers agree there is a strong association between complex trauma exposure and global cognitive functioning, there is mixed evidence about the specific cognitive processes that may underpin this association. This is due in part to fewer studies and smaller sample sizes (Zilberstein, 2014). For example, Viezel, Freer, Lowell, and Castillo (2015) found that while maltreated children in out-of-home care had lower achievement on measures of vocabulary, verbal comprehension and processing speed than a similar group of children without a history of trauma exposure, the groups did not differ on measures of working memory and perceptual reasoning.

The relationship between childhood trauma and developmental outcomes is not straightforward (Veltman & Browne, 2001), as individual functioning and recovery after trauma exposure varies widely (Gunnar & Quevedo, 2007; Institute of Medicine of the National Academies, 2013; Masten & Osofsky, 2010; Perkins & Graham-Bermann, 2012). In addition, it is now commonly understood in trauma research that different types of trauma experiences are often co-occurring (Gaskill & Perry, 2012; Glaser, 2000; Veltman & Browne, 2001), leading to difficulties in isolating discrete causes and effects. The complex nature of trauma has therefore made it difficult for stakeholders who work with traumatised children to identify points for intervention to promote resilience and recovery (Perkins & Graham-Bermann, 2012).

New understandings of childhood trauma

Developments in neuroscience and interdisciplinary research have advanced the field of childhood trauma research to move beyond a focus on outcomes to a focus on *developmental pathways* affected by trauma.

The developmental pathways affected by trauma exposure often go unrecognised, as research has historically treated the mind and body separately (Anda et al., 2006). More recently, trauma research has moved towards an interdisciplinary approach that examines the mind, brain and body together (Glaser, 2000) to understand the wide-ranging outcomes associated with childhood trauma (Gunnar & Quevedo, 2007; Schore, 2015).

Trauma research now recognises that a focus on adult trauma experiences is not appropriate for understanding childhood trauma exposure (Alisic, 2011; Briere, 1992), as children undergo critical periods of neurobiological development that are different from adults (Pechtel & Pizzagalli, 2011). Furthermore, childhood trauma research has moved away from a primary focus on clinical symptoms and outcomes associated with trauma (e.g. post-traumatic stress disorder) towards a neurobiological focus that considers the broad influence of trauma exposure on child development (Briere & Scott, 2015; Gaskill & Perry, 2012; Goodman, Miller, & West-Olatunji, 2012; Hodges et al., 2013).

Developmental trauma research now argues that trauma exposure during childhood affects children's self-regulatory capacities by disrupting the normal functioning of the body and brain stress-response systems, which can affect emotional and cognitive functioning (Putnam, 2006).

Neuroscience research has underscored the understanding that the brain is the central system linking neurobiological and psychosocial development, which can explain how trauma exposure may help initiate a 'cascade' of impaired functioning across seemingly unrelated pathways in childhood, adolescence and adulthood (DeGregorio & McLean, 2013; Kearney, Wechsler, Kaur, & Lemos-Miller, 2010; Pechtel & Pizzagalli, 2011). In addition, neuroscience research has shifted the focus from a cognitive perspective of the child brain to a primary focus on the emotional development of the brain (Schore, 2015). Environmental and relational experiences in childhood, for better or worse, influence neurobiological development, and therefore childhood trauma exposure has the potential to become the organising system of the brain (Perry, 2009).

While trauma exposure includes many types of experiences, the child's body and brain stress-response systems are finite, therefore the developmental pathways affected by trauma are more important to understand than the specific trauma experienced (De Bellis, 2001). Trauma will be physically 'remembered' (Glaser, 2000; van der Kolk, 1994) by children as physical states and sensations in response to both positive and negative experiences in their environment.

Body and brain stress-response systems

Stress response physiological systems

Research has identified two primary physiological systems involved in stress responses to trauma exposure:

- the SAM system (i.e. sympathetic-adrenal-medullary system), and
- the HPA axis (i.e. hypothalamic-pituitary-adrenal axis) (Yates, 2007).

What is the SAM system?

The SAM system is part of the body's sympathetic nervous system. It plays a role in short-term flight-or-fight responses to stress. The body physiologically responds to stress by releasing adrenaline, which increases sweat, heart rate and blood pressure, and reduces digestion (Van Horn, 2011).

The SAM system's activation also reduces a child's ability to engage in 'the present' by affecting body and brain systems involved in processes such as attention and memory (Gaskill & Perry, 2012).

Children with histories of trauma show evidence of disrupted functioning of the sympathetic nervous system, and may have higher baseline adrenaline and heart-rate levels (van der Kolk, 2003).

What is the HPA axis?

The HPA axis is part of the body's endocrine system and is involved in the body's longer-term responses to stress, regulating complex interactions between the body's hypothalamus, pituitary and adrenal glands. The HPA axis is also involved in regulating the immune system and emotions.

The HPA axis helps activate or deactivate glucocorticoid hormones (e.g. cortisol) in response to stress. Impaired functioning of the HPA axis has been identified as a key pathway between trauma exposure and later developmental outcomes (Kearney et al., 2010).

The HPA axis develops throughout childhood. Frequent activation of the HPA axis may lead to overloading the body's stress-response systems (Bradley & Corwyn, 2002) thereby damaging the body's central nervous system and organs. The HPA axis may then not activate when required, activate when not required, or continue to be activated after stress has subsided (Kearney et al., 2010).

Research has found irregular levels of glucocorticoid hormones in children with histories of trauma (Kearney et al., 2010), which has also been associated with reduced school engagement and academic achievement (Perkins & Graham-Bermann, 2012).

Glucocorticoid hormones affect brain and body systems through changes to gene transcription, which may help explain why changes to HPA axis functioning are related to longer-term physiological and developmental outcomes (Gunnar & Quevedo, 2007). Furthermore, impaired HPA axis functioning affects the way in which traumatised children respond to future stressors. It often takes lower stress levels to provoke full-blown stress responses. This may help perpetuate a cumulative effect of trauma throughout development (Grasso, Ford, & Briggs-Gowan, 2012).

Prolonged exposure to certain types of glucocorticoids have also been associated with impaired neural plasticity (Glaser, 2000), which is the brain's ability to reorganise itself in response to the environment.

New understandings of brain development in childhood

Developments in neuroscience research have helped to change understandings of how the brain develops during childhood and how physiological changes in response to stress can interact with a child's neurodevelopment. These neurodevelopmental principles have been advanced through new neuroimaging technologies and research methods (Hart & Rubia, 2012).

The developing brain is use-dependent, which means that when specific neural systems are frequently activated in response to environmental stimuli or stressors, these systems have the potential to become more permanent neural states for children (Gaskill & Perry, 2012). Therefore, contrary to previous thought, 'lower' brain systems involved in stress responses may not be wholly controlled by 'higher' brain systems, such as those involved in reasoning and inhibition. In times of acute stress, these lower-order systems can override other brain systems that are beyond a child's conscious awareness (Gaskill & Perry, 2012). This means that the brain does not interpret, store and respond to information in a hierarchical fashion, but is characterised by integrated responses involving various brain systems (van der Kolk, 2003).

Children's brains may be particularly susceptible to the timing and severity of trauma exposure as brain development in childhood is not linear (Pechtel & Pizzagalli, 2011). This means that brain structures and processes have different timing and patterns of development. For example, some regions develop most during childhood, others develop most during adolescence, and other regions continue to develop into adulthood. This may help explain, in part, wide-ranging variation in subsequent emotional and cognitive functioning among children after trauma exposure.

Interestingly, Pechtel and Pizzagalli (2011) also argue that some neuroscience research suggests that the genetic influence, or heritability, on the development of specific brain structures and regions varies according to age. Trauma exposure that occurs earlier in childhood may thus pose a risk for brain structures and regions that develop later, as they are less buffered by genetic influences earlier in development.

Brain structures and systems

Neuroimaging techniques have allowed researchers to study structural differences in the brains of children and adults with histories of childhood trauma. Evidence from neuroscience research suggests that trauma exposure may be more often associated with structural differences in the brain's:

- prefrontal cortex
- limbic system
- cerebellum, and
- corpus callosum.

These regions and structures have higher densities of glucocorticoid receptors, making them more sensitive to stress hormones such as cortisol, and some structures undergo protracted development throughout childhood, thereby making them more vulnerable to environmental stress during childhood (DeGregorio & McLean, 2013; Teicher et al., 2003).

While researchers have noted an association between trauma exposure and structural changes in the brain, they are cautious about not drawing causal inferences from these observed associations (Hart & Rubia, 2012; Pechtel & Pizzagalli, 2011).

Prefrontal cortex

Research strongly suggests childhood trauma exposure may be associated with structural changes and functioning in the prefrontal cortex, an area of the brain located in the front of the frontal lobes. The prefrontal cortex is an important area of the brain characterising mature cognition. It is involved in brain processes such as memory and attention, emotional and behavioural regulation and inhibition, personality, abstract reasoning and learning (Beers & De Bellis, 2002; Gunnar & Quevedo, 2007; Hart & Rubia, 2012). The prefrontal cortex is a brain region with protracted development and it has a high density of glucocorticoid receptors (Gunnar & Quevedo, 2007), making it more vulnerable to trauma exposure than other brain regions.

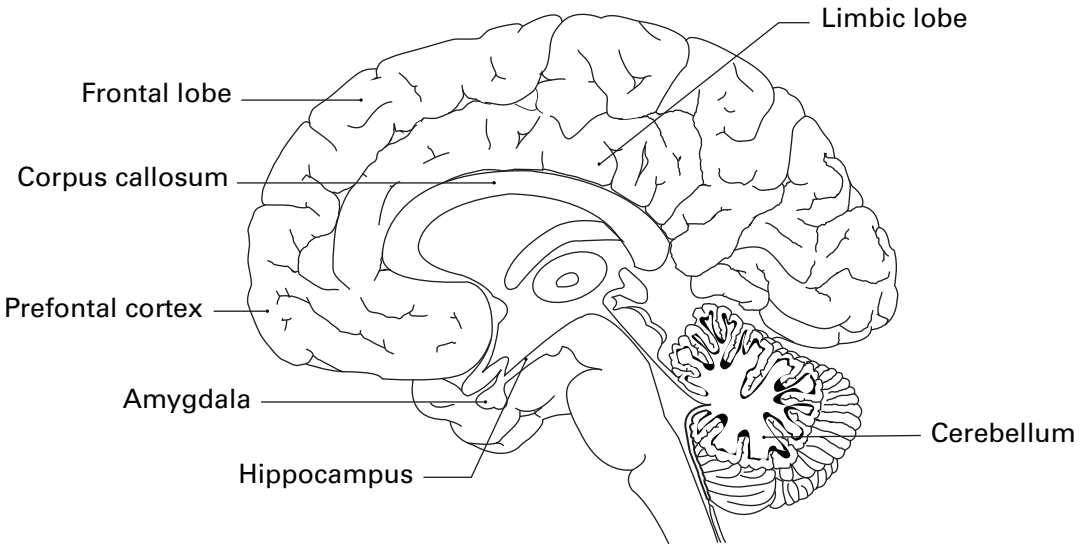
Neuroimaging research suggests trauma exposure may be associated with both increased and decreased volume of the prefrontal cortex, as well as deficits and abnormalities in grey and white matter volume (Hart & Rubia, 2012). Cognitive processing takes place within the brain's grey matter, which is involved in the brain's ability to reorganise itself, or neuroplasticity (Busso, 2014). White matter allows communication, or integrations between brain regions and grey matter (Hart & Rubia, 2012). These structural changes in the prefrontal cortex are hypothesised to be associated with problems with memory, emotional regulation and self-regulatory capacities (Cook et al., 2005).

Limbic system

Neuroscience research strongly suggests childhood trauma exposure, especially chronic or pervasive trauma, may be associated with observed changes in various limbic structures in the brain.

The limbic system involves many different brain structures sitting above the brainstem and under the brain's cortex, or outer layer, such as the hippocampus and amygdala, and plays an important role in emotion and memory (van der Kolk, 2003). The hippocampus is a brain structure in the limbic system involved in processing emotions, anxiety, associative memory (i.e. the ability to learn and remember the relationship between unrelated items or events), spatial memory and contextual learning (i.e. the ability to relate knowledge to personal experiences) (Pechtel & Pizzagalli, 2011). Neuroimaging studies consistently find evidence of reduced hippocampal volume in adults who have experienced childhood trauma. Evidence of changes to hippocampal volume and structure in traumatised children is more inconclusive (Hart & Rubia, 2012), suggesting structural changes in response to trauma exposure may take time to develop during childhood, and more longitudinal studies are needed (Van Horn, 2011).

Median section of the brain



The amygdala is a brain structure in the limbic system involved in fear responses during the body's flight or fight response to stress, making it a potential brain structure to be affected by trauma exposure. The amygdala is also involved in emotional memory and self-inhibition, particularly controlling aggression (Teicher et al., 2003). Neuroimaging research shows inconsistent structural differences in the amygdala between traumatised and non-traumatised children (Hart & Rubia, 2012), with some evidence suggesting there may be an association between childhood trauma exposure and abnormal volume of the amygdala (Hart & Rubia, 2012). Observed abnormalities in the amygdala's size have been hypothesised to be related to hyperarousal or over-activation of the amygdala in response to extreme stress. Overload, or abnormalities, of the amygdala could be related to observed aggressive or violent behaviour, particularly during adolescence and adulthood, for populations with histories of childhood trauma exposure (van der Kolk, 2003).

A focus on observed structural changes in the brains of traumatised individuals has underscored the importance of neural development as a mechanism influencing child development.

Cerebellum

The cerebellum is a structure located at the back of the brain, which is involved in diverse processes such as motor control, language, working memory, cognition and emotion (Pechtel & Pizzagalli, 2011; Teicher et al., 2003). The cerebellum also has a prolonged development period, potentially making it more vulnerable to environmental stress (Pechtel & Pizzagalli, 2011). There is consistent evidence from neuroimaging research of decreased cerebellum volume in children with histories of trauma exposure (Hart & Rubia, 2012). Researchers hypothesise that reduction in cerebellum volume may be related to observed disturbances in language, working memory and cognitive abilities such as planning (Pechtel & Pizzagalli, 2011; Teicher et al., 2003).

Corpus callosum

The corpus callosum connects the left and right brain hemispheres, allowing communication between them. It is involved in the development of brain lateralisation, the process by which the brain hemispheres undergo integrated development. The corpus callosum undergoes significant development in children from three to six years of age. This development relates to attention and behavioural planning. In children from six to 13 years of age, the corpus callosum develops significantly in relation to language and memory (Pechtel & Pizzagalli, 2011), which may underlie observed language impairments in some traumatised children (Zilberstein, 2014). Neuroimaging research has identified reduced overall size and reduced grey and white matter of the corpus callosum in traumatised children (DeGregorio & McLean, 2013; Hart & Rubia, 2012; Teicher et al., 2003; van der Kolk, 2003). Therefore, the timing of trauma exposure in relation to the development of the corpus callosum and brain lateralisation may differentially affect brain regions in traumatised children.

A focus on observed structural changes in the brains of traumatised individuals has underscored the importance of neural development as a mechanism influencing child development. However, researchers note limitations with neuroimaging technologies and research methods, and study limitations are often unable to control for other factors related to both trauma exposure and brain development, e.g. psychological disorders and psychiatric medications (Hart & Rubia, 2012; Pechtel & Pizzagalli, 2011). Therefore, an interdisciplinary approach examining the convergence between neuroscience and psychological research can bring this understanding closer together.

The corpus callosum undergoes significant development in children from three to six years of age. This development relates to attention and behavioural planning.

Self-regulation and attachment

Attachment is an essential mechanism by which children's brains and self-regulatory capacities develop, thereby allowing them to manage stressors and stimuli in their environments (Schore, 2015). Neuroscience has helped move attachment theory in psychology to a focus on self-regulation theory in neurodevelopment (Schore, 2015), underscoring the link between emotional experiences with caregivers and later neurobiological, emotional and cognitive functioning. Impaired self-regulatory capacities are often the first symptoms of trauma noticed by parents and teachers (Perkins & Graham-Bermann, 2012).

van der Kolk (2003) argues that parents and caregivers are the 'hidden regulators' of children's physiological stress-response systems, mediating their responses to stress in the environment and helping children develop their own self-regulatory capacities over time. Research has shown that children who have disrupted parental attachment are also likely to have evidence of impaired HPA axis functioning (Gunnar & Quevedo, 2007). Intense, relational experiences with caregivers help form an internal template for children's understanding of the world and of themselves (Perry, 2009). Children who experience trauma perpetrated by a caregiver often have poor self-concept, feeling they are worthless and unlikeable, which may be exacerbated by impaired emotional and cognitive skills.

Consequently, attachment and self-regulatory capacities are important mediating pathways for resilience or risk after trauma exposure. For example, a small, longitudinal study found that children who had insecure or disorganised parental attachment at 12 months of age and who experienced trauma, were more likely to have post-traumatic stress disorder symptoms at 8.5 years of age, than were traumatised children who were classified as having secure parental attachment at 12 months of age (Macdonald et al., 2008). Therefore, trauma exposure that disrupts parental attachment, such as child neglect and abuse, is particularly damaging for a child's development (van der Kolk, 2003). Conversely, positive attachment to caregivers and adults acts as a protective factor to help children develop self-regulatory capacities after trauma exposure.

Exploring emotional and cognitive functioning

Emotional functioning

Impaired self-regulation or emotional functioning is one of the most salient symptoms of trauma exposure, and can be broadly characterised as hyperarousal or withdrawal (Schore, 2001). Impaired emotional functioning after trauma exposure often involves altered abilities to interpret emotional states of self and others, as well as poor self-concept, poor behavioural control, impaired reward-processing abilities, and mistrust of social interactions and situations (van der Kolk, 2003).

Both psychological and neuroscience research show that traumatised children may have difficulties identifying their own emotional states in everyday situations, for example, distinguishing between feeling frustrated or scared (Cook et al., 2005). Hart and Rubia (2012) also note that traumatised children often have difficulties detecting and interpreting the emotional states of others, which may be due to traumatised children's attentional bias, or heightened sensitivity to potential threats and harm.

Related to attentional bias, research suggests traumatised children may need fewer emotional cues than non-traumatised children to detect anger in other people, and there is evidence of impaired functioning of the amygdala and the superior temporal gyrus (STG) in the brain, which are both involved in processing emotional and social cues (Pechtel & Pizzagalli, 2011). There is evidence that attentional bias in traumatised children may be less amenable to neural plasticity or return to normal functioning, in comparison to other brain processes affected by trauma exposure. Evidence of observed abnormalities in the amygdala and STG, as well as hyperarousal to detect anger and threatening cues, have been observed in children long after trauma exposure has occurred or ceased (Pechtel & Pizzagalli, 2011). Impaired emotion detection and identification may make it difficult for traumatised children to enact appropriate strategies to soothe and regulate their emotions, and respond appropriately to others (Cook et al., 2005).

Traumatised children may develop behavioural strategies to cope with their emotional responses to new stimuli or stressors in their environments. Impaired stress-response systems may cause traumatised children to overreact to changes in their environment as they are mistakenly perceived as threats. Children may behave in aggressive ways to protect themselves, such as engaging in bullying or defiant behaviour, or they may adhere to inflexible routines and rituals (Cook et al., 2005). In addition, as traumatised children show more symptoms of attentional bias, their hyperaroused stress-response systems may use attentional resources to monitor the environment for threats and stressors, increasing the likelihood of disengagement from everyday activities and relationships (Schore, 2001).

Traumatised children may develop behavioural strategies to cope with their emotional responses to new stimuli or stressors in their environments.

Poorer emotional and behavioural functioning may also be related to impaired functioning of the brain's reward processes after trauma exposure. Reward processing is important for the development of goal-directed behaviour. This means children can respond to reward-predicting cues or 'wants', for example, cues that motivate children to participate in fun and pleasurable activities. Some research suggests impaired functioning of basal ganglia (a group of structures in the brain) after trauma exposure may reduce reward-seeking behaviours. Therefore, impaired abilities to appropriately respond to reward-predicting cues may be associated with withdrawal symptoms and increased risk for psychological disorders, such as depression (Pechtel & Pizzagalli, 2011). In addition, reward processing refers to the ability to learn from rewarding outcomes (Pechtel & Pizzagalli, 2011). Strong evidence from neuroscience research shows impaired functioning of the brain's reward processes may also be related to children's increased risk of using inappropriate help-seeking strategies to deal with future stress and challenges (e.g. substance abuse, self-harm, risky sexual behaviour), thereby increasing their risk of further victimisation and trauma exposure (Cook et al., 2005; Pechtel & Pizzagalli, 2011).

Cognitive functioning

Traumatised children may develop diverse cognitive styles and coping strategies to accommodate their stress responses (Cromer, Stevens, DePrince, & Pears, 2006). Research suggests children who have problems with self-regulation are often removed from mainstream classrooms and placed in special learning environments. This may further reduce opportunities for developing appropriate school functioning and cognitive abilities (Perkins & Graham-Bermann, 2012).

Trauma exposure fosters bidirectional and cumulative effects on development, such that impaired cognitive, emotional and psychological functioning may reinforce poorer outcomes across these same developmental pathways (Bücker et al., 2012). While there is evidence in both psychological and neuroscience research of an association between childhood trauma exposure and cognitive functioning, the causal pathways between factors are still unclear (Hart & Rubia, 2012).

Executive function

Neuroscience research has highlighted that brain regions in the prefrontal cortex and frontal lobes may be at increased risk to the effects of trauma exposure. These brain regions are associated with development of executive function, which refers to a variety of interrelated abilities such as attention, working memory, self-regulatory and monitoring skills, behavioural inhibition and cognitive processing speed (DePrince, Weinzierl, & Combs, 2009). The development of executive functioning is essential to be able to interpret and respond to new information and experiences in the environment. Research hypothesises that observed increases in executive functioning in childhood may correspond to intense periods of growth in the prefrontal cortex, from birth to approximately two years of age, seven to nine years of age, and during adolescence and into adulthood (Pechtel & Pizzagalli, 2011).

Both psychological and neuroscience research have reported 'global' deficits in executive functioning in children with histories of trauma exposure

Both psychological and neuroscience research have reported 'global' deficits in executive functioning in children with histories of trauma exposure (Pechtel & Pizzagalli, 2011). Research also suggests that development of executive function may be affected in a variety of ways after trauma exposure. Research from neuroimaging studies suggests traumatised adolescents show less activation in regions of the brain associated with inhibitory control than non-traumatised peers do when undertaking tasks where they are asked to inhibit or provide responses to verbal cues or commands (Pechtel & Pizzagalli, 2011). Neuroscience research also suggests childhood trauma exposure may be related to observed difficulties in auditory and visual attention (Hart & Rubia, 2012).

A small study examining executive functioning in traumatised and non-traumatised children from similar sociodemographic backgrounds found that traumatised children performed worse on an attention task due to increased susceptibility to distracters and more impulsive responses (Beers & De Bellis, 2002). Interestingly, the traumatised children did not meet clinical criteria for post-traumatic stress disorder, which is similar to a study conducted by Bücker et al. (2012), which also tested traumatised and non-traumatised children on tasks relating to executive function. These studies suggest traumatised children may have impaired executive functioning that would not typically be detected in other assessments by health or education systems.

Memory

Some neurological evidence suggests an association between trauma exposure and impairments in short and long-term memory (Hart & Rubia, 2012); however, a review of neurological and clinical studies concluded that the relationship between child maltreatment and impaired memory processes (i.e. encoding, storage, retention and retrieval) is inconclusive (Howe, Cicchetti, & Toth, 2006). Similarly, neurological evidence for an association between observed abnormalities in the amygdala and hippocampus, and memory impairments, is inconsistent in studies of both traumatised children and adult populations (Pechtel & Pizzagalli, 2011; Teicher et al., 2003).

Another small body of research examining memory and trauma exposure suggests *psychological symptoms* of dissociation may be related to trauma exposure and impaired cognitive functioning (Perzow et al., 2013). Dissociation refers to changes in a child's memory and consciousness, such that thoughts and consciousness are dissociated from physical sensations and experiences in the external world, as well as from emotions and behaviours in the internal world (Schore, 2001). Dissociation may be a useful strategy to cope with traumatic experiences (DePrince et al., 2009; Perzow et al., 2013). Research suggests childhood trauma exposure and increased symptoms of dissociation may be related to observed problems with behavioural inhibition, auditory attention, working memory, cognitive processing speed (Cromer et al., 2006; DePrince et al., 2009), as well as negative perceptions of school membership and academic self-competence (Perzow et al., 2013).

Dissociation refers to changes in a child's memory and consciousness, such that thoughts and consciousness are dissociated from physical sensations and experiences in the external world, as well as from emotions and behaviours in the internal world

It is important for educators and stakeholders working with trauma-exposed children to understand the relationship between dissociative symptoms and cognitive functioning, as symptoms of dissociation may often be interpreted as other developmental disorders (Cromer et al., 2006), or teachers may interpret dissociative symptoms, such as being withdrawn or 'frozen', as behavioural problems (O'Neill, Guenette & Kitchenham, 2010).

Implications for practitioners

This synthesis of current neuroscience, psychology and education research highlights children's vulnerability to the effects of trauma. Furthermore, the normal cognitive, emotional and social competencies required to function effectively in the school environment may be incredibly challenging to the already disrupted body and brain systems of traumatised children, further exacerbating problems with their school functioning.

Unfortunately, traumatised children may feel teachers do not understand their needs, and school supports after trauma exposure may decline over time (Dyregrov, 2004) although research suggests that effects of trauma exposure may be long lasting. Alisic (2011) notes that research to date has rarely considered the role of the teacher and school in promoting resilience after trauma exposure. However, many key developmental pathways affected by trauma exposure can also be supported within schools to help children re-establish self-regulatory capacities and healthy development.

Research has identified three areas where teachers and schools can focus attention to support traumatised children's needs: attachment, competencies and self-regulation (Cole, Greenwald O'Brien, & Gadd, 2005; Gregorowski & Seedat, 2013). DeGregorio and McLean (2013) highlight the importance of teachers and schools in fostering attachment, competencies and self-regulation through repetitive, predictable and nurturing behaviours.

Different approaches to behaviour management in schools can help traumatised children learn how to regulate their emotions and behaviour. Many factors may cause trauma-informed behaviour, and teachers should not be afraid to try different strategies to find out what is most effective for children in their classrooms.

Trauma-informed emotional and behavioural responses may make it challenging for teachers to respond positively and predictably to traumatised children (Downey, 2007). Gregorowski and Seedat (2013) note that frequently developmental trauma involves the betrayal of trust from caregivers, making it difficult for children to trust adults, even when an adult's behaviour is positive. However, developing positive attachment to a teacher or mentor is vital to helping traumatised children normalise their disrupted body and brain stress-response systems, and to develop self-regulatory capacities (Dods, 2013; O'Neill et al., 2010).

The development of positive attachment may be helped through a teacher's 'unconditional positive regard' for a child (Brunzell, Waters, & Stokes, 2015), warmth and expressing joy in a child's accomplishments (Cole et al., 2005). As many traumatised children experience difficulties in school functioning and may have poor self-concept, it is important for traumatised children to feel that teachers and schools consistently care about and appreciate them, regardless of how well they perform in school (Dods, 2013).

Teachers may provide traumatised children with opportunities to improve competencies and to develop a self-concept that may be unrelated to academic achievement, such as giving them special jobs they can master such as distributing learning materials in class (Cole et al., 2005). Teachers can help identify children's interests and talents that can be integrated into the classroom, which may help traumatised children develop feelings of self-competence and re-engage them in their learning (Downey, 2007). To develop self-competencies and positive attachment, traumatised children need opportunities to 'explore, play and learn' without negative or punitive consequences, with the help of a predictable, positive adult (Gregorowski & Seedat, 2013).

Different approaches to behaviour management in schools can help traumatised children learn how to regulate their emotions and behaviour. Many factors may cause trauma-informed behaviour, and teachers should not be afraid to try different strategies to find out what is most effective for children in their classrooms (Australian Childhood Foundation, 2010).

In general, strategies should first aim to support children to regain control over their bodies' sensations to perceived stress through soothing environments (Gaskill & Perry, 2012). Classrooms and schools may create 'safe spaces' where children can calm themselves when teachers notice symptoms of hyperarousal or withdrawal (Cole et al., 2005). Traumatised children may also be provided with opportunities in schools to positively re-experience physiological sensations through activities such as dance, singing, music, sports, breathing and meditation exercises (Brunzell et al., 2015; Gaskill & Perry, 2012). Anticipating potential stressors and consistently reminding children of changes to their routine can help traumatised children to anticipate and plan their emotional and behavioural responses (Cole et al., 2005).

In general, strategies should first aim to support children to regain control over their body's sensations to perceived stress through soothing environments

Incentive-based behavioural management strategies are often ineffective for traumatised children as they may have disrupted reward-processing abilities. Instead of withdrawing rewards or providing warnings for negative behaviour, teachers can address negative behaviour directly and calmly by pointing out the negative emotion or behaviour, and offering to help children address their difficulty and re-engage in the classroom task (Downey, 2007). Traumatised children may first need help from teachers to recognise and label their emotions and reactions before they can learn new strategies for regulating stress responses.

Learning activities may present traumatised children with many cognitive challenges that may arouse their trauma-informed stress responses. Teachers can provide traumatised children with structured learning supports to help children re-engage in learning activities and reduce stress.

Practical strategies to address learning challenges may include:

- helping children to break down tasks into small, manageable steps
- repeating information or providing written instructions
- establishing routines through planning and prompting next steps, and
- using visual cues and reminders to help children monitor their behaviour, and scaffolding tasks by allowing children to work alongside classmates (Australian Childhood Foundation, 2010; DeGregorio & McLean, 2013).

A better understanding of the developmental pathways associated with trauma exposure may help stop trauma symptoms from being attributed to low ability or behavioural problems (Goodman et al., 2012). Educators and schools already have many of the skills and resources to help traumatised children (Cole et al., 2005), and can promote healthy development through a holistic focus on attachment, competencies and self-regulation.

This paper recognises that teachers and schools are not suitably equipped or resourced to provide clinical therapies and treatments, nor establish the environmental safety of traumatised children, which are the roles of medical and social service providers (Gregorowski & Seedat, 2013). However, research notes that current models of clinical treatment alone cannot address the needs of trauma-exposed children. Teachers and other mentors are essential to help traumatised children, through intense and regular positive social interactions, to re-establish normal functioning of body and brain stress-response systems (Gaskill & Perry, 2012). Furthermore, trauma research notes that early interventions are much more effective for helping traumatised children than are reactive services (Perry, 2009), and policy can aim to support teachers and schools to address the needs of traumatised children in classrooms.

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