MIND, BRAIN, AND EDUCATION

How Early Life Adversity Transforms the Learning Brain

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ABSTRACT— For educators to help children exposed to adverse life experiences, it is necessary to understand how adversity impacts different mechanisms of learning, emotion, and planning as these capacities underpin success in schools and beyond. The goal of this paper is to review essential findings on how early life adversity transforms the brain which, in turn, impacts educational outcomes. Part 1 begins by discussing the species-specific and expectant experiences that guide typical development, and then turns to early life adversities and their relationship to both physical and mental health outcomes. Part 2 summarizes four dimensions of adversity—*type*, *timing*, *term*, and *toxicity*—and how each differentially impacts the developing brain, including individual differences in psychopathology. Part 3 discusses the relevance of these findings for educators, highlighting how behavior can be modified to build resilience and greater academic and social–emotional competency.

Throughout the world, children experience adversity, including emotional and physical neglect, poverty, war, physical and sexual abuse, family dysfunction and mental health problems (Asmundson & Afifi, 2020; Blum, Li, & Naranjo-Rivera, 2019). Analyses of data from the World Health Organization suggest that close to 40% of all children have experienced one or more types of adversity before the age of 18 years, with little difference between high- and low-income countries (Kessler et al., 2010). Bellis et al. (2019) estimate that the total annual cost of such adverse childhood experiences is $748 billion in Europe and $581 billion in North America. Some individuals respond to such adversity with internalizing and externalizing symptoms. Adversity, in this sense, entails situations in which there are atypical environmental perturbations that are serious or severe, often chronic, and necessitate significant adaptive responses (McLaughlin, 2016). As Nelson, Bhutta, Harris, and Danese (2020) suggest, it is important to distinguish between the adverse events that happen to the child or *toxic stress*, and the child's response to such events or the *toxic stress response*. Not all children exposed to toxic stress have a toxic stress response, and some who were not exposed—as indicated by official records—nonetheless have the subjective experience as adults of a toxic stress response (Danese & Widom, 2020). These patterns suggest important individual differences in perceived experience and resilience that stem from both nature and nurture (Dennison et al., 2016; McLaughlin, DeCross, Jovanovic, & Tottenham, 2019; Moreno-López et al., 2019).

Children with a history of early life adversity, as well as ongoing adverse experiences, often present with poor educational outcomes (Almond, Currie, & Duque, 2017; Jimenez, Wade, Lin, Morrow, & Reichman, 2016; McKelvey, Edge, Mesman, Whiteside-Mansell, & Bradley, 2018; Robles, Gjelsvik, Hirway, Vivier, & High, 2019; Sheridan & McLaughlin, 2016; Stempel, Cox-Martin, Bronsert, Dickinson, & Allison, 2017). At a relatively coarse-grained level, several studies show that children growing up in economically disadvantaged homes, as indicated by low SES, perform much less well on executive functioning tasks of working memory, inhibition, and planning than do peer-matched students with high SES (Duncan, Yeung, Brooks-Gunn, & Smith, 1998; Hardcastle et al., 2018; Sarsour et al., 2010). This relationship between deprivation and poor executive functioning is further reinforced by studies of children raised in orphanages, with evidence that the negative impact on performance persists and often grows by adolescence (Wade, Fox, Zeanah, & Nelson, 2019). Critically, executive functioning is one of the most significant predictors of school readiness, transition to kindergarten, literacy and math skills, as well as high school graduation and successful transition to college (reviewed in Zelazo, Blair, & Willoughby, 2016). On a more fine-grained level, chronic school absenteeism (>15 days/year) is significantly more common for children (6–17 years old) witnessing or experiencing neighborhood violence than those without such adversity; the more adverse early childhood experiences, or ACEs, the more significant the absenteeism (Stempel et al., 2017). Similarly, in a study

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of children in England and Wales, 62% of those with four or more ACEs had no educational qualifications beyond primary school or employment as adults compared with only 3% for those with 0 or 1 ACE (Hardcastle et al., 2018). In a study by Jimenez et al. (2016), kindergarten students with three or more ACEs had below average language, literacy and math scores, and greater attentional, social and aggression problems. The longer a child is exposed to these early life adversities, the stronger the impact on educational outcomes.

Recognizing the relationship between early life adversity and educational outcomes has led to significant developments around the support and creation of trauma-sensitive schools (Souers & Hall, 2016). However, because of rapid scientific growth in understanding how adversity impacts the developing brain (Gunnar & Reid, 2019; Sheridan & McLaughlin, 2020; Teicher, Samson, Anderson, & Ohashi, 2016), there is an urgency to not only disseminate such information, but translate it into practical, actionable instructional approaches (McLaughlin et al., 2019). The goal of this review is to discuss some of the significant advances in the field and then raise a few promising implications and directions for translational work.

PART 1. SPECIES-SPECIFIC EXPERIENCES AND ADVERSITIES

All species have evolved developmental mechanisms that guide them from conception to maturity (Briscoe & Ragsdale, 2018; Levis & Pfennig, 2020; Wagner, Chiu, & Laubichler, 2000). Such developmental processes depend critically on specific experiences, including their timing and coordination with maturational processes. For all vertebrates, there are both *sensitive* and *critical* periods that constrain when and how different capacities develop (Reh et al., 2020). Sensitive periods represent biologically defined phases where certain kinds of experience are necessary for building species-specific capacities; in the absence of experience, the capacity may not develop or may develop in a more impoverished form. Critical periods are also defined by phases of development, but in the absence of experience, the capacity simply fails to develop, and thus the impact is permanent. Both sensitive and critical periods therefore represent times in development where the brain is most plastic, where experience effectively instructs brain development, and where the absence of experience or the occurrence of insult can lead to atypically developing systems (Gottleib, 2002; Gunnar & Reid, 2019; Werker & Hensch, 2015).

Consider phonemic discrimination and face recognition, two different systems, each associated with critical periods (Maurer & Werker, 2013). Both capacities are domain-specific in the sense that they rely on specialized neural circuitry that is restricted to a narrow range of inputs, and when damaged, reveal highly specific deficits; no one has to instruct the young child as to what constitutes a face or a phoneme, as both systems are innately tuned to be sensitive to the key features of each domain. Further, the circuitry for processing faces is not involved in processing phonemes, and the phonemic circuitry does not process faces.

When the developing individual is deprived of species-specific experiences or is exposed to violence, directly or indirectly, the prognosis for healthy, species-typical outcomes are reduced, especially when such adversity occurs during critical periods where neural plasticity is heightened. Invasive studies of nonhuman animals, including deprivation as well as experimentally induced stress caused by physical harm, lead to substantial or complete failures of perception, communication, attachment, emotional regulation, and social discrimination (Lupien, McEwen, Gunnar, & Heim, 2009; Nelson & Gabard-Durnam, 2020; Thomason & Marusak, 2017). Though studies of human development have also pointed to the relevance of species-specific experience for proper development, much of the evidence is correlational, stemming from either naturally occurring “experiments” (e.g., genetic mutations, brain damage, neurodevelopmental disorders) or opportunities to assess responses to naturally occurring adversities (e.g., poverty, lack of education, sexual abuse, war) that arise as a function of individual and societal differences (Bick, Fox, Zeanah, & Nelson, 2017; Chen & Baram, 2015; Sheridan & McLaughlin, 2020).

An important development in the field, especially in terms of global awareness of the relationship between early life adversities and later life mental and physical outcomes, was the survey-based research findings of Felitti and colleagues (1998). Based on analyses of responses (9,508 American adults) to a 10-question survey about ACEs, results showed a strong positive association between the number of ACEs and the relative severity of the health outcomes. Though the survey itself distinguished between different types of adversity (e.g., neglect, family dysfunction, physical abuse), the overarching approach has been a cumulative risk model in which the number of ACEs are tallied and correlated with health outcomes (Evans, Li, & Whipple, 2013). There is now ample support for this model, including cross-cultural and international evidence (Anda, Butchart, Felitti, & Brown, 2010; Blum et al., 2019).

The significance of the cumulative risk model of ACEs cannot be understated. Not only has this research brought greater awareness to the medical community of the devastating impact of early adversity on health, but has significantly mediated change in public policy, insurance, and overall attitudes toward child health. There have, however, been challenges and extensions to this work that has direct bearing on the translational issues that matter most to educators: the relationship between early adversity and different learning mechanisms, including what, if anything, can be done to build resilience and enhance academic and social–emotional competencies and outcomes.

PART 2. TYPE, TIMING, TERM, AND TOXICITY OF ACES

The cumulative risk model does not distinguish between different types of adversity, nor when they occurred, for how long, and with what level of severity. Furthermore, the foundational evidence for this model is self-report, often provided by adults well after the adverse experience occurred. As Sheridan and McLaughlin (2016, 2020) have argued, when we treat all adversities similarly, we learn little about the mechanisms linking adversity to specific forms of psychopathology, be they internally or externally manifested. And to understand the mechanisms, we need to go beyond self-report (Danese & Widom, 2020; Widom, 2019).

Considerable research with nonhuman and human animals suggests that different *types* of adversity impact different neural circuits which, in turn, differentially impact learning and behavior. In addition to the *type* of ACEs, recent studies also emphasize three other dimensions of the event, what I will refer to as the *timing*, *term*, and *toxicity* of ACEs — or the four Ts of adversity (Figure 1). *Timing* refers to when adversity occurs in relationship to the development of the nervous system and body. *Term* refers to how long the adverse event lasts, and *toxicity* refers to the relative severity of the event. I discuss next the potential of each dimension of adversity to transform the learning brain.

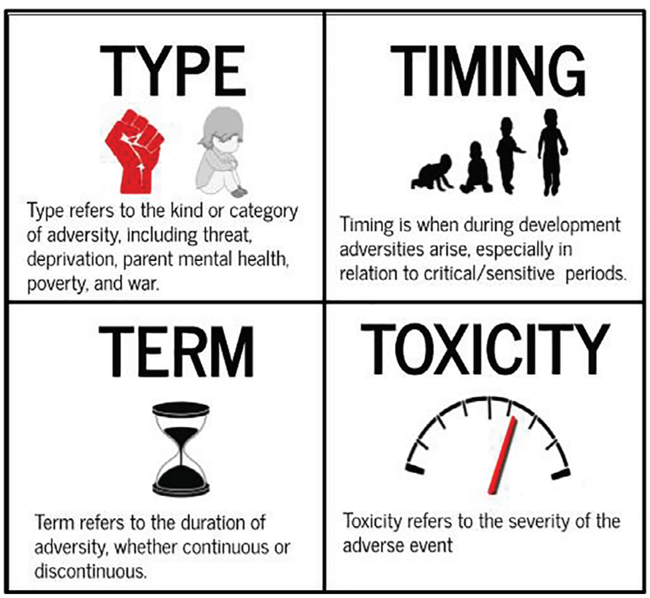

Fig 1. The four Ts of adversity. Clockwise from the top: Type, timing, toxicity, and term.

Building on decades of research on animals, together with their own studies of human infants, children and adolescents, Sheridan and McLaughlin (2016, 2020); Sheridan, Shi, Miller, Salhi, & McLaughlin, 2020) developed the *dimensional model of adversity and psychopathology (DMAP)*, emphasizing the unique signatures of two types of adversity: threat and deprivation. Threat-based adversities involve either direct or indirect harms, including sexual and physical abuse, as well as exposure to community violence. Deprivation-based adversities entail significant deviations from species-specific experiences that are required for typical mental and physical development including poverty, emotional neglect, and institutionalization. Though other types of adversity are likely, and other ways of carving up the space plausible (see Smith & Pollak, 2020), there is considerable evidence to support the threat-deprivation distinction.

Threat-based adversities are consistently associated with heightened emotional reactivity and dysregulation, as well as biases in threat-perception, including earlier acquisition of a fear response, overgeneralization of anger perception, and excessive allocation of attentional resources to potential threats (Lambert, King, Monahan, & McLaughlin, 2017; Pollak & Tolley-Schell, 2003); emotional reactivity and dysregulation are, however, also observed in children with only deprivation-based adversities, absent the selective bias that children exposed to threat-based adversities express toward anger. Physiologically, there is significant evidence that threat-based adversities are related to changes in the stress response (Herzberg & Gunnar, 2020; Lupien et al., 2009; Porges, 2018a), including blunted sympathetic and parasympathetic responses as well as reduced cortisol levels (Busso, McLaughlin, & Sheridan, 2017). Furthermore, those exposed to threat-based adversities show enhanced reward processing in terms of heightened response to or motivation for positive cues, whereas children experiencing deprivation show reduced reward processing. As further discussed in Part 3, emotional regulation, attentional focus, and reward processing represent integral, domain-general capacities for navigating the social and academic demands of a school; children with emotional disabilities and attentional disorders show significant delays in achieving academic milestones, gaps that have doggedly impacted special education (Gage, Adamson, MacSuga-Gage, & Lewis, 2017; Lewis, Wehby, & Scott, 2019).

Different forms of threat-based adversities also appear to be related to more selective changes in the brain (Teicher et al., 2016), providing parallels to some of the selective deficits shown in patients with brain damage (e.g., prosopagnosia). For example, women who were exposed to sexual abuse as children show cortical thinning of the genital area of the somatosensory cortex, whereas those exposed to emotional abuse show thinning in areas involved in self-evaluation and awareness (Heim, Mayberg, Mletzko, Nemeroff, & Pruessner, 2013). For individuals exposed as children to parental verbal abuse, but no other adversities, there is evidence of a reduction in the integrity of the arcuate fasciculus, a neural bridge that links Broca's and Wernicke's areas, and thus highly relevant to linguistic competence (Choi, Jeong, Rohan, Polcari, & Teicher, 2009). Though such research is in its infancy, it raises the possibility that even more fine-grained distinctions within the two core types proposed by Sheridan and McLaughlin may be helpful in understanding the relationship between mechanisms and outcomes.

Deprivation-based adversities present with a different neuro-cognitive signature (Nelson, Zeanah, & Fox, 2019). In parallel with research on threats, insights into the causal relationship between deprivation and brain development started with work on rodents and nonhuman primates, including experimental manipulations of sensory and social experience, titrating both the timing (e.g., sensitive or critical periods), term, and toxicity of the deprivation (Robbins, 2016; Zhang, 2017). The impact of sensory deprivation has been assessed in children born deaf or with cataracts who, in some cases, have hearing or vision restored at some point in development by means of surgery (Maurer, 2015, 2017). In contrast, the most significant insights into how social deprivation impacts the brain have come from randomized control studies of children institutionalized from birth or soon thereafter, who either remain institutionalized until early adulthood or are placed in foster care at some point during childhood (Fox, Nelson, & Zeanah, 2017; Lee, 2020; Nelson et al., 2019; Orben, Tomova, & Blakemore, 2020; Tottenham et al., 2010; Wade et al., 2019). Accompanying this more extreme form of deprivation is more correlational research looking at the negative impact of low SES, home dysfunction (e.g., divorce, substance abuse), food insecurity, low parental education, and the 2020 Covid-19 pandemic of social isolation on health and critical education metrics (e.g., Brooks-Gunn & Duncan, 1997; Hardcastle et al., 2018; Rosen, Sheridan, Sambrook, Meltzoff, & McLaughlin, 2018; Sarsour et al., 2010; Sheridan, Sarsour, Jutte, D'Esposito, & Boyce, 2012).

Though there have been many studies of the impact of institutionalization on child development, research emerging from the Bucharest Early Intervention Project provides some of the richest insights as it is based on a randomized control trial design, where some children were removed from the orphanage and placed in foster care during different periods of development. In addition, the project's focus has been to combine different kinds of evidence, including molecular, neural, hormonal, cognitive, and behavioral to identify the mechanisms linking adversity to health outcomes (Berens & Nelson, 2015; Nelson et al., 2019). Compared with children raised by their biological parents, or institutionalized children placed in foster care by 6–33 months, institutionalized children show significantly thinner cortical grey matter, reduced white matter tracts connecting the prefrontal cortex with both the temporal lobe and the striatum, and lower power (Bick & Nelson, 2016). A significant cognitive and behavioral outcome of these neural differences is that institutionalized children show poor executive functioning (self-regulation, working memory, cognitive flexibility), a blunted stress response, and poor motivation due to lower activation of the reward system. In addition, and as would be expected given the lack of parental care and minimal care taker interactions, institutionalized children often show attachment disorders, including both inhibited and disinhibited forms (Gunnar & Reid, 2019; Zimmermann & Soares, 2018). Each of these neurocognitive outcomes are either directly or indirectly related to deficits in educational performance. They also place unique strains on the staff in a school, mandating not only great sensitivity to the triggers that may dysregulate a child, but attention to modifications and accommodations in instruction designed to address deficits in executive functioning and motivation to learn more generally.

A striking example of the devastating impact of deprivation on the learning brain comes from an elegant experiment by Sheridan et al. (2018) with three groups of 12-year old children: a) never-institutionalized, b) institutionalized, and c) foster care following 6–33 months of institutionalization. Each child's performance was assessed on two tasks that required associative learning: the first assessed the child's ability to build an association between a visual cue and a reward, the second required creating an association between a specific number and a specific motor action; these basic associative learning mechanisms underpin the early acquisition of reading and math competences, with evidence that impairments cause significant delays in attaining grade-relevant milestones (Chong & Siegel, 2008; Tijms, Fraga-González, Karipidis, & Brem, 2020). For the reward-association task, performance by never-institutionalized and foster children was the same, and significantly better than the institutionalized children. For the implicit motor task, the never-institutionalized and foster children again outperformed the institutionalized children, but the foster children did not perform as well as the never-institutionalized; it is unclear whether such differences in recovery were due to differences in the plasticity of the neural systems involved or to the sensitivity of the tasks. Overall, however, when foster care is provided during what appears to be a sensitive period of development, the associative learning mechanism largely recovers its species-typical competency. These results lead naturally into the other dimensions of adversity.

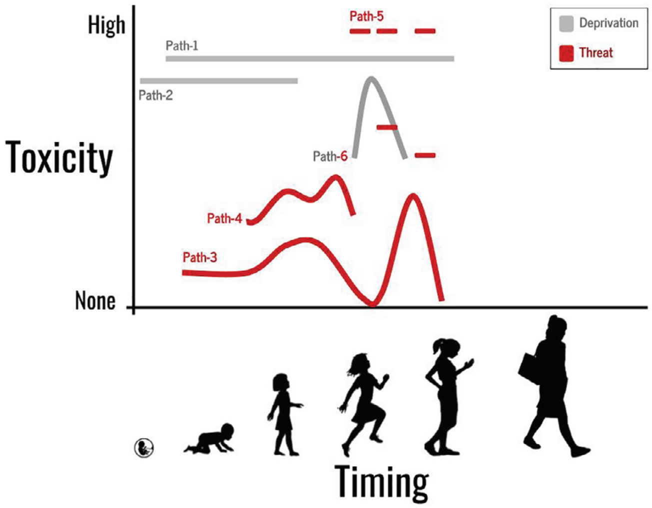

Fig 2. Developmental paths of adversity. The space is defined by the timing x-axis and toxicity y-axis. Type is represented by Deprivation in grey and Threat in red, whereas Term is represented by the length of each path, including both continuous and discontinuous periods of adversity; though there are multiple types of adversity, and potentially different ways of carving up the typology, the focus in this review is on deprivation and threat. Paths 1–5 represent cases where the Type of adversity is homogeneous, whereas Path 6 represents a case where the types are mixed or heterogeneous.

Figure 2 provides a schematic of the potential interplay between the four dimensions of adversity. The space is defined by the axes of Timing and Toxicity of the adverse events and populated by different paths, linked to the Type of adversity and its Term. For illustrative purposes, I have plotted six hypothetical paths associated with different patterns of exposure to adversity. Path-1 captures the situation for children institutionalized from birth to adulthood, where the toxicity or level of deprivation is extremely high. Path-2 illustrates a child institutionalized from birth, who then enters the nurturing environment of foster care as a toddler. Path-2 is also associated with maternal deprivation which directly impacts fetal development, including exposure to intrauterine stress hormones (van den Bergh et al., 2017); though not discussed in detail here, there is considerable evidence of intergenerational, epigenetic effects, showcasing the potential for genetic and environmental factors to have a long lasting impact on mental and physical health (Augsburger, Basler, & Maercker, 2019; Mulligan, 2015; Warmingham, Rogosch, & Cicchetti, 2020).

Paths 3–5 are associated with pure threat-based adversities, with differences of timing, toxicity, and term; term not only varies by overall duration but whether it is continuous and to some extent predictable. In Path-3, the child is continuously exposed to threats until early adulthood, with varying degrees of toxicity or severity. Path-4 starts in the toddler age and then ends in early adolescents, with a relatively narrower range of toxicity. Path-5 represents high levels of toxicity, occurring discontinuously and briefly, starting in early adolescence and ending in the teenage years. Finally, Path-6 illustrates a case involving a combination of deprivation and threat, varying in toxicity, timing, and term. The abrupt onset of deprivation shown in this path is akin to the experience that many adolescents encountered during the Covid-19 pandemic of 2020, in which global enforcement of social-distancing effectively blocked the fundamental ability to interact during what many consider a sensitive period of development (Bzdok & Dunbar, 2020; Fuhrmann, Knoll, & Blakemore, 2015).

The reason for raising the idea of a space of adversity anchored by the 4Ts of adversity is twofold. First, an increasing number of studies have made inroads into pinpointing the relationship between changes in brain, cognition and behavior with different types of adversity, as well as when they arise, their severity and duration. Though this work is still in its infancy, with few studies directly linking particular paths of adversity to educational outcomes, evidence of the mapping between adversity type and neural impact is emerging. Figure 3 illustrates some of the ways in which the two different types of early adversity impact both unique and overlapping brain circuits, and how the impacted circuitry relates to different cognitive processes, some domain-general and some domain-specific. Second, both the timing and type of adversity are relevant to the critical or sensitive periods associated with specific competencies that underpin student success in the school environment. As such, understanding how exposure to adversity may be related to delays in some competencies, while prematurely activating others, is of direct relevance to teachers attempting to customize their instructional approaches to enhance educational outcomes.

Consider the relationship between deprivation, brain circuitry and cognitive processes (Figure 3). The toxicity and term of deprivation inhabits a space or spectrum, ranging from the extremes of an orphanage (Paths 1 and 2) to children living in low SES families. As noted, removing a child from highly toxic deprivation as may occur in orphanages (i.e., Path 2) benefits the associative learning mechanisms. In addition, institutionalized children placed in foster care before 20 months acquire higher adaptive functioning (e.g., mental and physical health, executive functioning, family relationships, academic performance) at age 12 years than children who remain in the orphanage or are placed in foster care later (i.e., Path 1) (Humphreys et al., 2018). Lastly, children growing up in low SES families consistently show weaker performance on standardized tests and general competencies in math and reading when compared with children in high SES families, with the duration of time or term in poverty showing a positive correlation with the magnitude of educational deficits (Lacour & Tissington, 2011). Thus, both the type, timing and term of deprivation are related

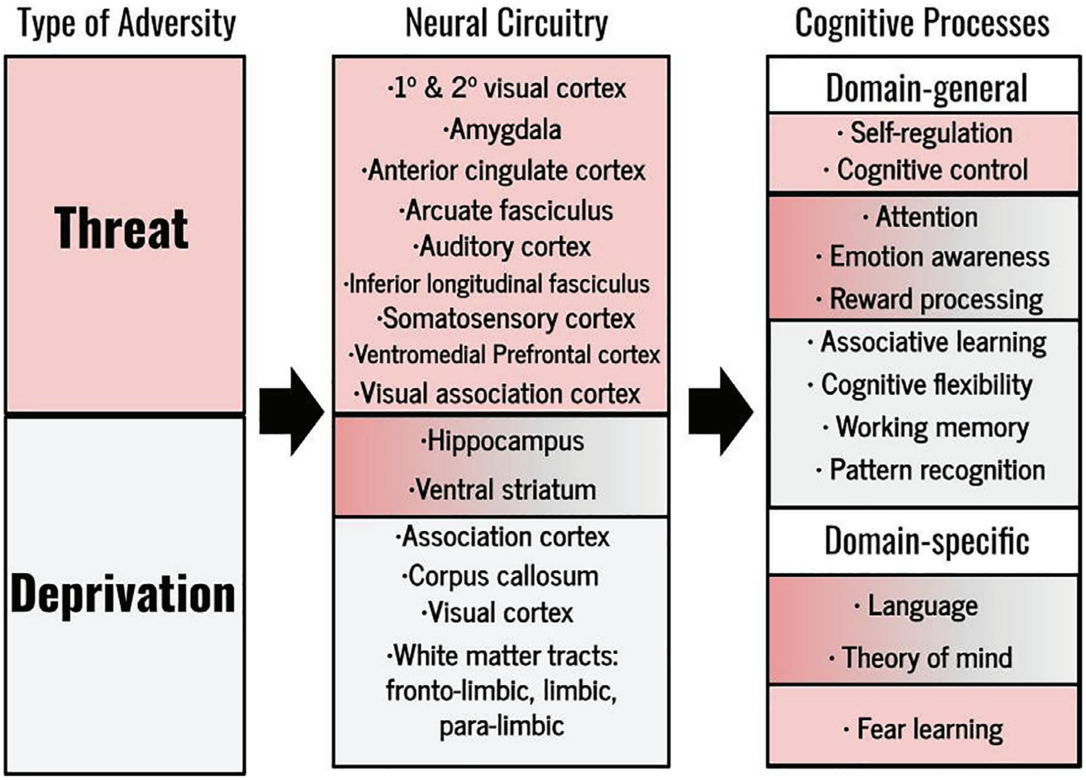

Fig 3. How type of adversity impacts neural circuitry and cognitive processes. Neural circuits and cognitive processes affected by threat-based adversities are shaded in red, whereas those impacted by deprivation are shaded in gray; red-gray shading refers to systems affected by both threat and deprivation.

to the acquisition of several domain-general competencies that contribute to in-school performance and general life skills.

In terms of threat, and sexual abuse most specifically, evidence reveals that hippocampal volume in females is more vulnerable early in development (3–6 years), whereas grey matter volume in the prefrontal cortex is more vulnerable in adolescents (13–17 years) (Teicher et al., 2016). Studies of assaultive violence reveal that toxicity and timing (before age 13) are negatively correlated with the functioning of prefrontal and occipital cortices, and positively correlated with the extent of externalizing aggressive behavior in adulthood (Bounoua, Miglin, Spielberg, & Sadeh, 2020). A study by Herzog et al. (2020) directly compared the type, timing and toxicity of adversity in adult females using structural MRI with regions of interest focused on the amygdala and hippocampus. Results showed that deprivation, as opposed to threat, was the primary driving force, with amygdala and hippocampal volumes negatively correlated with the relative toxicity of neglect, and the greatest vulnerability occurring between preadolescence and early adolescence. Lastly, and in the largest study to date—3,872 individuals, ages 13–89 years—results showed that the greater the toxicity of experienced adversity, the greater the extent of cortical thinning, irrespective of adult psychopathology (Tozzi et al., 2020); the thinning was particularly notable in areas involved in social cognition, including areas critical for the domain-specific, theory of mind competency (Figure 2). The type of maltreatment — deprivation or threat — was not related to cortical thickness, whereas a combination of both types was associated with significantly thinner cortices. A sex difference was also observed, with males showing greater cortical thickness in the anterior cingulate cortex, an area involved in emotional self-regulation. Given the lack of longitudinal or resiliency data, it is not clear whether this difference in thickness provided an adaptive response; there is some evidence that high-quality care-giving can buffer the child against cortical thinning (Luby, Belden, Harms, Tillman, & Barch, 2016), a benefit that would pay off in terms of the social–emotional and relational factors that underpin academic success in schools.

One striking aspect of the results presented thus far, as well as others (Birn, Roeber, & Pollak, 2017), is that a significant percentage of individuals show no relationship between the toxicity or timing of the adversity and neurocognitive functioning (Dennison et al., 2016; Holz, Tost, & Meyer-Lindenberg, 2020; McLaughlin et al., 2019;

Moreno-López et al., 2019). For example, in a study by Sonuga-Barke et al. (2020), results from the Romanian Adoptee study show that 20% of children entering the foster care system after 6 months of institutionalization showed no internalizing or externalizing psychopathology in adulthood. These results point to the significance of resilience, driven by nature and nurture.

Individual differences are important for policy, health insurance, screening, and of course, education. Critically, just because an individual has been exposed to toxic stress does not determine how he or she will respond to it. Those who do respond to toxic stress with a toxic stress response are cognitively vulnerable, while also experiencing accelerated aging, including an earlier onset of puberty (Colich, Rosen, Williams, & McLaughlin, 2019; Jovanovic et al., 2017). Even individuals who do not show externalized signs of psychopathology due to adversity, perhaps because of intense reliance on self-regulation, may suffer from accelerated aging, a process that may impact health in adulthood (Miller, Yu, Chen, & Brody, 2015). Understanding vulnerability and resilience to adversity is critical to enhancing the quality of instruction in all schools.

PART 3. IMPLICATIONS AND APPLICATIONS FOR EDUCATORS

To illustrate opportunities for educator intervention, I turn next to three different patterns of adversity as illustrated in Figure 1, starting with Paths 1 and 2, the two pure cases of deprivation As Sheridan, McLaughlin, and Nelson's research shows, children who leave the orphanage before 24 months, largely recover the associative learning mechanisms. However, this early departure does not re-calibrate the stress response that is mediated by the hypothalamic–pituitary axis. In particular, institutionalized children raised in foster care show a blunted cortisol response. There is perhaps nothing more basic or foundational to the learning brain than association and a properly calibrated stress response. Children who cannot form simple associations, cannot learn school rules or the mechanics of early math and reading. With a blunted stress response, the motivation and reward systems are miscalibrated as is the social information processing system. These challenges are joined by other domain-general (e.g., cognitive flexibility, working memory) and domain-specific mechanisms (e.g., language processing) that are critically linked to educational outcomes (McKelvey et al., 2018; Miller, Machlin, McLaughlin, & Sheridan, 2020; Rosen et al., 2018; Sarsour et al., 2010; Sheridan et al., 2012).

A fascinating study by Gunnar et al. (2019) shows that puberty provides an opportunity for recalibrating a stress response that has been blunted by deprivation, and more generally, an opportunity for educators to positively impact an adolescent brain that exhibits a renewed window of plasticity, including enhancing student-teacher relationships (e.g., Roubinov, Boyce, & Bush, 2020). Using the Trier Social Stress Test (Kirschbaum, Pirke, & Hellhammer, 1993), in which an individual has to give a speech and answer math problems in front of an unfamiliar group of judges, results showed that the cortisol profile of post-institutionalized girls was increasingly similar to never-institutionalized girls as pubertal stage increased. Further, the recalibration of the stress response during puberty occurred irrespective of age of adoption, at least within the range assessed (5.5–59 months), suggesting that the term of deprivation does not adversely impact the potential plasticity of the brain to recalibrate during puberty. Because toxic deprivation is associated with poor executive functioning, as well as atypical autonomic reactivity (Porges, 2018b), the pubertal period of plasticity represents a critical window of opportunity to positively shape these domain-general systems, that directly impact educational outcomes (Colich et al., 2019; McLaughlin et al., 2019; Porges et al., 2014; Sullivan et al., 2018).

Next consider the pure threat-based adversity paths 3–5. Threat-based adversities show a different signature of impact on the brain (Figure 3) than do deprivation-based adversities, with additional modifications imposed by the timing, toxicity, and term, as well as the specific kind of threat (e.g., physical, sexual or emotional abuse). For example, physical abuse appears to have a significant impact on social information processing as a result of deficits in both cognitive and affective aspects of theory of mind (Sebastian et al., 2012). The theory of mind system typically matures during the first 4–5 years of life, allowing children to understand their own and others' intentions, beliefs and desires, as well as the morally-relevant emotions of empathy, sympathy, guilt, and shame. If these systems are damaged during the critical period of development, when the system is most plastic, then subsequent delays and challenges in social information processing are likely to ensue. Such challenges may well be expressed in terms of frustration due to lack of comprehension, which may, in turn lead to shutting down or aggression. As several studies reveal, children who have been subjected to physical abuse often respond with aggression, thus perpetuating a cycle of violence (Heleniak & McLaughlin, 2020). For educators, the key is to recognize that some forms of aggression stem from poor social information processing, and thus, an important target for intervention is both the affective and cognitive theory of mind system (Kim et al., 2016; Sebastian et al., 2012). Several studies show that systematic training of belief-desire psychology, empathy, compassion, and language is positively related to enhanced social information processing (Hale & Tager-Flusberg, 2003; Klimecki, Leiberg, Ricard, & Singer, 2014), which is critical to reducing several of the well-established gaps in educational attainment associated with social–emotional disabilities (Lewis et al., 2019).

Children exposed to threat-based adversity also show accelerated fear learning, biased allocation of attentional resources to threatening faces, and overgeneralization such that non-threatening situations are often perceived as threatening. These attentional biases are associated with both a general psychopathology factor (Weissman et al., 2019), as well as more specific disorders such as anxiety, depression, psychosis, and PTSD (McLaughlin, Colich, Rodman, & Weissman, 2020). The challenge for schools working with such children is that a multitude of individuals and situations may trigger a fear response, leading to bolting, aggression, and significant disruptions of attention. A promising approach to altering the response to threatening stimuli is attention bias modification training (Bar-Haim, 2010; Lisk, Vaswani, Linetzky, Bar-Haim, & Lau, 2020). The method, a version of the dot-probe-task (MacLeod, Mathews, & Tata, 1986), entails showing a pair of stimuli, using either words or facial expressions. The two stimuli are presented one on top of the other. Following presentation, the two stimuli disappear and a target probe appears in the position of one of the stimuli, with subject reaction time recorded. The paired stimuli are either both neutral or one neutral and one threatening, and the target probe either appears in the position of a neutral stimulus or in the position of the threatening one. With attention bias modification, the target probe is disproportionately located in the neutral position, effectively nudging subjects to attend to this position and away from the threatening stimulus. Though this task has not, to my knowledge, been used with children or adults who have experienced threat-based adversity, it has been effectively used to reduce anxiety in 6–18 year olds with social anxiety disorder, and for those with attentional disabilities, improved attentional focus (Pergamin-Hight, Pine, Fox, & Bar-Haim, 2016). Given the low cost of implementation, and its potential to modify attention and triggering from threat-based stimuli, attention bias modification is a potentially powerful tool for educators to use in combination with other effective emotion-regulation strategies such as mindfulness (Bauer et al., 2019).

As a final illustration, consider children experiencing either threat-based adversity (Paths 3–5) or a combination of threat and deprivation (Path-6). A common pattern is that such children experience heightened emotional reactivity and poor self-regulation, two outcomes that rely on domain-general capacities. Here, both the toxicity of the adversity as well as the timing matter a great deal, as the systems involved in emotional awareness and expression mature earlier than those involved in self-regulation, and adolescence is naturally a period of heightened risk-taking along with a heightened need for social interaction (Duckworth & Steinberg, 2015; Fuhrmann et al., 2015; Steinberg et al., 2018). Emotional reactivity can be triggered by many experiences within a school, including interactions with staff that remind them of an abusive parent, the sight of aggression among other children, witnessing or experiencing physical restraints, and frustration from school demands. Such triggers pose a serious dilemma for educators deciding between general education inclusion programs and alternative education programs specifically designed for children with emotional disabilities. Whereas inclusion enables students with emotional disabilities to mix with the general education population, and potentially grow from the models that others provide, if the disability is severe, and expressed with aggression toward others, it may not be possible to address their needs. On the other hand, though alternative education programs are well equipped to help students with significant emotional disabilities, including those caused by toxic stress, such students are exposed at a much higher frequency to the potentially triggering experiences of other students' emotional outbursts, including aggression. In either school setting, there are interventions that can help to reduce emotional reactivity by means of either directly strengthening the self-control system or providing alternative habits that effectively bypass the need to use self-control, including methods that effectively calm the autonomic nervous system by means of chemical, sensory and neural feedback, and behavioral modification through mindfulness (Bauer et al., 2019; Keynan et al., 2019; Porges et al., 2014; Smigielski et al., 2019; Tang, Posner, & Rothbart, 2013).

CONCLUSION

For several decades, it has been clear that early childhood adversities have a dramatic impact on mental and physical health outcomes. Such adversities are blind to geography and to some extent, socio-economic status. As revealed by the cumulative risk model, the more adversities a child experiences, the greater the likelihood of negative health outcomes. Recent research has expanded understanding by recognizing the significance of different types of adversity, as well as their timing, term and toxicity. As reviewed, different types of adversity have potentially different transformative effects on the brain that manifest in different developmental challenges for children. Further, the timing, term and toxicity of these adversities can affect the degree of impact, including most specifically, experiences that arise during sensitive or critical periods of development when the brain is most plastic. Periods of heightened neural plasticity represent opportunities for experience to sculpt both domain-general and -specific systems. If such experiences are negative, they can result in great harm. These insights linking different dimensions of adversity to changes in the brain are critical to educators that have opportunities to help children build resilience. There is no one-shoe-fits-all approach to early life adversity, as the different dimensions of adversity are related to different brain mechanisms. By appreciating the differences, and taking advantage of the methods that scientists have developed and applied, educators will be in a much stronger position to enhance growth in children who have suffered, and may continue to suffer, from the transformative effects of early life adversity.

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CONFLICT OF INTEREST

There is no conflict of interest for the content of this manuscript.

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