The Effects of Adverse Childhood Experiences on Long-Term Brain Development and Health

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Childhood trauma is the ghost of childhood that haunts victims for the rest of their lives. Although childhood trauma occurs towards the beginning of life, its drastic effects on development last forever. Dr. Nadine Burke Harris (2014) defines childhood trauma as "threats that are so severe or pervasive that literally get under our skin and change physiology" (1:08). Experiences of childhood trauma, called Adverse Childhood Experiences (ACEs), are the constant presence of traumatic actions against a child, such as abuse or neglect. These experiences negatively shape a child's development by creating a stressful, unsafe environment and caregiver presence. As a result of being consistently exposed to stressful environments, toxic stress — a significant component of ACEs — can appear in early life. Toxic stress explains why ACEs can "get under the skin" of children, while affecting their overall development ("ACEs and Toxic Stress," Harvard Center on the Developing Child, 2020c). It is crucial to understand that ACEs have both immediate and long-lasting detrimental effects that have significant impacts long into adulthood. These effects impact brain development, behavior, and health.

There are many categories of ACEs and many long-term health effects that arise from early childhood adversity. According to Felleti et. al (1998), regarding their ACEs study, there are seven categories of ACEs — "psychological, physical, or sexual abuse; violence against mother; or living with household members who were substance abusers, mentally ill or suicidal, or ever imprisoned" (p. 245). It is very common for these categories to overlap in a single household because some categories, such as substance abuse, have the potential to cause the presence of other categories, such as abuse (Felleti et. al, 1998). Many other research studies have been conducted to study the distribution of these categories. One such study (1998), conducted by Robert Anda, a Centers for Disease Control epidemiologist, and Vincent Felitti, a preventative medicine doctor, involved the issuing of a survey to a middle-class population to evaluate their childhood experiences. Of the 17,337 people surveyed, 64% reported having at least one ACE, with 12.4% experiencing four or more ACEs (Anda & Felitti 1998, as cited in Crawford County Human Services, 2016). Anda and Felitti's study reveals the daunting presence of early adversity and serves as an example for the presence of ACEs in mainstream society.

Furthermore, their study revealed a disturbing relationship between a person's ACE score and their risk for lifelong health problems: as the number of ACEs one experiences increases, their risk for poor outcomes also increases. Not only does early adversity have an intense presence in society, it has the ability to increase the likelihood of life-threatening diseases later in life. Therefore, experiencing ACEs have the ability to haunt children throughout their entire lives.

The presence of ACEs can drastically affect a child's brain, which results in disruptions in both cognitive and physical development. One of the primary impacts of early adversity on the brain is within the stress response system. When children are born, their stress response systems are not fully developed, and like the rest of their brain, are vulnerable to adverse experiences. In an adverse environment in which children are consistently exposed to a stressful and potentially dangerous atmosphere, their brain will react by releasing excessive amounts of stress hormones, like adrenaline and cortisol (Minnesota Department of Health, 2013). This then triggers the "fight or flight" response, which is regulated by the hypothalamic-pituitary-adrenal (HPA) axis. This causes the HPA axis to go into hyperdrive, manipulating a potentially life-saving response into a threat to their brain development. In a situation where a child's HPA axis is consistently activated, their brain responds by going into "survival mode," which means all other higher-functions are limited. When in survival mode, the brain activates only its lowest component in its hierarchy of function. The hierarchy of function consists of the brainstem, the diencephalon, the limbic system, and the neocortex. The brainstem is responsible for the regulation of body temperature, heart rate, and blood pressure. Next is the diencephalon, which is responsible for arousal, motor regulation, alertness, vigilance, appetite, and sleep. Then, there is the limbic system — consists of four subcomponents called the hippocampus,

thalamus, hypothalamus, and amygdala — which is responsible for long-term memory, emotional reactivity, and sexual behavior. Finally, there is the neocortex, which is responsible for attachment, abstract and concrete thought, and affiliation. To summarize, the hyperactivation of the stress response system negatively impacts the development of the higher-level components of the hierarchy of function in the brain. In other words, high-stress situations cause parts of the brain to "shut down" in this survival mode, making it more difficult to focus, concentrate, and perform other executive functions.

To develop to its full potential, a child's brain must receive high levels of stimulation. At birth, an infant's brain is neither structurally developed or fully functioning. In early childhood, a child and infant's brain is dependent on relationships to shape their brain's structure and function. According to the Carnegie Corporation of New York (1994), children need close relationships with only a small number of caring people to achieve healthy development (p. 39). As children are raised, their brains register whatever environment they grow up in as "normal," and they mirror whatever is in front of them. If a child is neglected or harmed, their brain will shape their experiences as "normal," and their cognitive and overall brain development will fall behind. The Harvard Center on the Developing Child (2020a) suggests that the absence of a "serve and return" relationship — the continuous back and forth interaction between caregiver and child — can cause a child's brain architecture to not form properly and have disparities in learning and behavior ("In Brief," 2020a, p. 1). When a child is consistently exposed to ACEs, the impacts of those experiences on brain development appear immediately but can last through adolescence and into adulthood. Usually, the brains of children who have one or more ACE are most likely not to be properly stimulated.

The level of neglect and lack of stimulation in early childhood directly affects development in adolescence. According to Stephen D'Orazio (2016), adolescence is the period in which neurological connections, or synapses, are formed between the prefrontal cortex and limbic system. In the brain, the prefrontal cortex (PFC) governs executive function while the limbic system mediates emotion. In the relationship between the PFC and limbic system, "The PFC exhibits top-down control over limbic regions and governs the regulation of emotions. Thus, exposure to adverse experiences during this period in brain development may elicit problems in emotion regulation" (D'Orazio, 2016, para. 7). Therefore, neglect is one of the leading causes of adversity that affects development.

Adverse environments pose a risk to overall brain development in adolescence. Due to "the absence of an optimal environment or when the early environment elicits maladaptive adaptations, this sensitivity [to environmental experience] poses challenges for the brain to reach its full genetic potential" (para. 7). Thus, the negative impacts of ACEs in adolescence are built on those formed in early childhood; as a result, both high executive function of the brain and genetic potential are not reached.

In adulthood, the long-term impacts of toxic stress and adversity in early childhood grow more apparent, particularly in the stress response system. Because of the lack of stimulation and constant stress during childhood, toxic environments cause the executive functions of the brain to "shut down," resulting in a permanent lack of sufficient input. Therefore, consistent toxic stress in a child's environment results in fewer and weaker neural connections in the areas of the brain that are associated with reasoning and learning in adulthood, such as the prefrontal cortex. Dan Siegel (2012) suggests that the lack of neurological stimulation in early life results in apoptosis, or cell death; the longer a child is neglected, the more connections are prematurely pruned, which causes permanent developmental delays that snowball into adulthood (p. 22). Because the brain was impacted by ACEs in earlier life stages, developmental delays do not just "appear," but have been around all along and are more identifiable in adulthood.

In early childhood, trauma impacts every system in the body, and also negatively affects the complex interactions between them. The American Academy of Pediatrics (2014) has identified five key research findings that explore the variety of effects of childhood trauma. These findings include: incomplete brain structure at birth; environmental cues guiding brain structure; interaction with people to stimulate neural connections; experience impacts gene expression; within neuroendocrine structure; and all of the body's systems interact mutually (AAP, 2014). To clarify what the American Academy of Pediatrics (AAP) has found, when an infant is born, their brain comes into the world like a new block of clay. In other words, it is dependent on caregivers and the environment to sculpt the brain to normal development; this characteristic

of early development is referred to as "brain plasticity." To shape the brain, the formation of strong neural connections must occur through the process of hardwiring. The AAP further suggests that to achieve healthy brain development, a child is "dependent on adequate nutrition and the absence of toxins such as alcohol, mercury, lead, other drugs, and toxic stress" (AAP, 2014, p. 3, para. 6). Then, throughout infancy, a baby's brain adapts to everything around them, such as what they see, hear, and feel. Furthermore, AAP (2014) suggests toxic stress and neglect prohibit an infant's brain from achieving proper structural growth because such growth "depends on a nurturing, loving, and stimulating environment" (p. 3, para. 8). From birth, humans depend on relationships for stimulation and learning. In situations which children and infants are neglected and not given proper stimulation, their developing brain's needs are not being met because their new neural connections are not being consistently revisited through stimulation. As a result, this constant experience with toxic stress has the ability to permanently alter gene expression and brain architecture. Therefore, when exposed to a toxic or harmful environment, the impacts that environment has on the brain have the potential to impact other systems in the body (AAP, 2014). Most often, toxic stress is the product of a harmful environment.

Consistent toxic stress also has long-term impacts on overall health. The MinnesotaDepartment of Health (2013) states the hyperactivation of the stress response system is proven to produce disruptions to mental health and metabolic and immune systems, in terms of lifelong health (p. 9). The damaging effects of toxic stress on a child's immune system increase the risk for disease throughout adulthood. This helps emphasize and explain how interactions, processes, and systems within the human body and brain can be impacted in early childhood by adversity. These impacts extend from gene expression to interactions between major body and brain systems. Therefore, these findings prove ACEs have drastic immediate impacts in all aspects of development.

Toxic stress starts in the womb and has severe impacts on the stress response system that affect both gene expression and overall brain development. Dr. Jack Shonkoff (2019), an expert on early childhood development, reveals "'Toxic stress is not about the cause of the stress. It's the biological response to stress. And an environment that is fraught with stress affects gene expression. It affects how some genes turn on and off,' and has the potential to impact development 'from the moment of conception until the moment you die'" (as qt. in Sy, 2019). There are many ways in which the stress response system can be activated, such as exposure to neglect, verbal abuse, or physical abuse. Furthermore, Harvard University (2020b) explains how toxic stress causes lifelong developmental impacts. They emphasize that toxic stress causes the continuous activation of the stress response system, and explain that this system can be activated even when there is no apparent physical harm to the child. The child's stress systems are continually activated because there is no presence of a supportive adult. Eventually, a child's stress response system will be permanently set on high alert ("Toxic Stress," Harvard Center on the Developing Child, 2020b). There are many ways in which the stress response system can be activated, such as exposure to neglect, verbal abuse, or physical abuse. Therefore, toxic stress has the ability to impact a child's entire lifespan and alters both gene expression and overall development.

When a child's stress response systems are permanently on high alert, their executive functions will be permanently "shut down," causing severe developmental delays. There are many ways in which the stress response system can be activated, such as exposure to neglect, verbal abuse, or physical abuse. When the stress response system is activated, the brain reacts by eliciting a series of complex interactions within its structures. Joan Kaufman et. al (2000) identifies the main structures involved in the stress response system as the medial prefrontal cortex, hypothalamus, amygdala, and brain stem; overall, the stress response system is mediated by the HPA axis (Joan Kaufman et. al, 2000). In other words, the stress response system dominates the entire brain, and heavily involves regions of the brain that regulate mental and emotional development. When a child is exposed to toxic stress, it limits communication between different structures of the brain, preventing the child from accessing other interactions throughout the neocortex, which would allow the child to process information and learn. If a child were to be exposed to toxic stress from prenatal development to adulthood, they would experience extreme developmental delays and be incapable of processing information outside of their stressful environment.

When a child or adolescent experiences adversity, there is a disruption in behavioral development. For one thing, they may have trouble managing their emotions; this is due to the continuous stressful connection of the prefrontal cortex (PFC). If processes within these areas of the brain are disrupted by forms of adversity — such as neglect, verbal abuse, and physicalabuse — maladaptations appear resulting from a child's environment, or absence of an ideal environment. This, according to Stephen D'Orazio (2016) "poses challenges for the brain to reach its full genetic potential" (p. 1, para. 7). Thus, the negative impacts of ACEs in adolescence are built on those formed in early childhood. In adolescence, the impacts of adverse experiences carry over to negatively impact the brain's executive function and the relationship between the prefrontal cortex and limbic system. Stephen D'Orazio (2016) further explains that throughout childhood, connections are formed between modality-specific regions of the brain; and in adolescence, these connections are connected to association regions and synapses between frontal and parietal association grow stronger. As a result, both high executive function of the brain and genetic potential are not reached.

The impact of ACEs on the limbic system results in the increase and enhancement in behavioral and emotional problems in middle childhood. Behavior problems that arise during this stage in life are reflective of a child's experience with ACEs and are therefore unique to them, like a fingerprint. However, the central cause of behavioral problems is the inability to regulate emotional responses. One pediatric study conducted by Tenah Hunt et. al (2017) found that children who have had exposure to four or more ACEs are 33 times more likely to display behavioral problems than children who have not been exposed to ACEs. Furthermore, this study analyzed clinical levels of externalizing (eg., aggression) and internalizing (eg., anxiety, depression) behavioral problems, along with focusing on the clinical presence of Attention Deficit Hyperactivity Disorder (ADHD) diagnoses. When analyzing the connection between the prevalence of ADHD diagnosis and exposure to ACEs, Hunt et. al (2017) found "compared to children with 0 ACEs, those with 2, 3, and 4 or more ACEs had 1.7, 1.8, and 2.7 times the odds, respectively, of having an ADHD diagnosis" (Tenah Hunt et. al, 2017, para. 30). In sum, the findings proved the connection between exposure to childhood adversity and the amount of behavioral problems apparent in early adolescence. Finally, the study revealed a stronger correlation between adversity and externalizing behaviors than adversity and internalizing behaviors. Therefore, in adverse environments, the inability to regulate emotions in early childhood can grow into severe behavioral problems and possibly develop into ADHD. Behavioral problems are caused by the inability to regulate emotions stemming from a poorly structured limbic system, caused by an unstable and unpredictable environment in early childhood.

The impacts of ACEs on brain development are still apparent throughout adulthood, particularly the stress response system in relation to health. The Minnesota Department of Health (2013) states "Continuous activation of the stress response system can also produce disruptions of the immune and metabolic systems, resulting in a lifetime of greater susceptibility to physical illness as well as mental health problems" (p. 9). When a person is consistently exposed to adversity or toxic stress in early childhood and adolescence, their stress response becomes hyperactivated, which can adversely affect mental and physical health in adulthood. Additionally, according to an article published by Harvard University (2020b), the child's stress systems are continually activated because there is no presence of a supportive adult. Eventually, a child's stress response system will be permanently set on high alert, causing drastic results on long-term brain development. For example, toxic stress results in fewer and weaker neural connections in the areas of the brain that are associated with reasoning and learning ("Toxic Stress," Harvard Center on the Developing Child, 2020b). This constant stress "turns off" the higher functions in the neocortex, resulting in weaker connections within the prefrontal cortex or other areas of executive functioning. This "shifts" brain development to focus on the area of the brain which is being activated the most, such as basic functions, like survival, found in the brainstem. Therefore, the impacts of ACEs on the stress response system have life-long health impacts.

When exposed to a toxic environment throughout childhood and adolescence, a person's fight-or-flight response is consistently activated, causing the brain and body to significantly reduce executive functions related to health. This overactivation can lead to severe health problems in adulthood. In an analysis of the links between severe health problems and ACEs, Crawford County Human Services (2016) identifies the following as possible lifelong effects of severe childhood trauma: obesity, diabetes,

depression, suicide attempts, heart disease, cancer, stroke, chronic obstructive pulmonary disease (COPD), STDs, smoking, alcoholism, and drug use. Hyperactivation of the stress response system is not a choice; however, some people who have experienced toxic stress use coping mechanisms that may have negative long-term impacts. On the other hand, there are other long-term health effects of ACEs that arise solely due to prolonged exposure to adversity. That being said, Anda and Felitti (2016) also discovered a relationship between a person's ACE score and their risk for lifelong health problems: as the number of ACEs one experiences increases, their risk for poor outcomes also increases. For example, "someone with an ACE score of four had twice the risk of cancer and heart disease" (Crawford County Human Services, 2016, 3:03). Therefore, in those who have experienced adversity, the increased prevalence of health problems in adulthood occurs due to consistent disruptions to the body's immune system and ability to adapt. Some of these health problems are due to choices made throughout life as coping mechanisms for trauma, such as smoking and alcoholism. Thus, there is a strong relationship between ACEs and the appearance of health risks in adulthood.

Adversity and toxic stress are not a singular occurrence; they are experiences that impact brain development and affect mental and physical health through all life stages. Trauma is not a collection of past experiences but acts as a phantom that haunts victims throughout life. Adverse Childhood Experiences (ACEs) have severe impacts on overall brain and body development that become apparent in childhood, adolescence, and adulthood. The impacts of trauma can appear as early as in the womb and have the ability to permanently shape the brain away from healthy development. Without intervention, the inability to regulate the mind, emotions, and body causes a cascade of adverse responses that last long into adolescence and adulthood. This all results in an increased susceptibility to mental health and life-threatening health problems. Although it is difficult to prevent the long-term effects of ACEs, early intervention has the ability to help children get back on track. However, until society addresses ACEs as a public health crisis, the effects of ACEs will be felt for and through generations to come.

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