NATIONAL SCIENTIFIC COUNCIL ON THE DEVELOPING CHILD

# Excessive Stress Disrupts the Architecture of the Developing Brain

WORKING PAPER 3

Center on the Developing Child HARVARD UNIVERSITY

# NATIONAL SCIENTIFIC COUNCIL ON THE DEVELOPING CHILD





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**About the Authors**

The National Scientific Council on the Developing Child is a multidisciplinary, multi-university collaboration designed to bring the science of early childhood and early brain development to bear on public decision-making. Established in 2003, the Council is committed to an evidence-based approach to building broad-based public will that transcends political partisanship and recognizes the complementary responsibilities of family, community, workplace, and government to promote the well-being of all young children. For more information, go to www.developingchild.harvard.edu/council.




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# The Issue

THE FUTURE OF ANY SOCIETY DEPENDS ON ITS ABILITY TO FOSTER THE HEALTHY DEVELOPMENT OF the next generation. Extensive research on the biology of stress now shows that healthy development can be derailed by excessive or prolonged activation of stress response systems in the body and the brain, with damaging effects on learning, behavior, and health across the lifespan. Yet policies that affect young children generally do not address or even reflect awareness of the degree to which very early exposure to stressful experiences and environments can affect the architecture of the brain, the body's stress response systems, and a host of health outcomes later in life.

Learning how to cope with mild or moderate stress is an important part of healthy child development. When faced with novel or threatening situations, our bodies respond by increasing our heart rate, blood pressure, and stress hormones, such as cortisol. When a young child's stress response systems are activated in the context of supportive relationships with adults, these physiological effects are buffered and return to baseline levels. The result is the development of healthy stress response systems. However, if the stress response is extreme, long-lasting, and buffering relationships are unavailable to the child, the result can be toxic stress, leading to damaged, weakened bodily systems and brain architecture, with lifelong repercussions.

Not all stress is harmful. Stressful events can also be tolerable, or even beneficial, depending on how much of a bodily stress response they provoke and how long the response lasts. These aspects of the response, in turn, depend on the duration, intensity, and timing of the stressful experience, as well as its context, such as whether the experience is controllable, how often and for how long the body's stress system has been activated in the past, and whether the affected child has safe and dependable relationships to turn to for support. Because a child's ability to cope with stress in the early years has consequences for physical and mental health throughout life, understanding the nature and severity of different types of stress responses to early adverse experiences can help us make better judgments about the need for interventions that reduce the risk for later negative impacts.

**Positive stress** refers to moderate, short-lived stress responses, such as brief increases in heart rate or mild changes in the body's stress hormone levels. This kind of stress is a normal part of life, and learning to adjust to it is an essential feature of healthy development. Adverse events that provoke positive stress responses tend to be those that a child can learn to control and manage well with the support of caring adults, and which occur against the backdrop of generally safe, warm, and positive relationships. The challenges of meeting new people, dealing with frustration, entering a new child care setting, getting an immunization, or overcoming a fear of animals each can be positive stressors if a child has the support needed to develop a sense of mastery. This is an important part of the normal developmental process.

> **Healthy development can be derailed by excessive or prolonged activation of stress response systems in the body and the brain.**

**Tolerable stress** refers to stress responses that have the potential to negatively affect the architecture of the developing brain but generally occur over limited time periods that allow for the brain to recover and thereby reverse potentially harmful effects. Tolerable stress responses may occur as a result of the death or serious illness of a loved one, a frightening accident, an acrimonious parental separation or divorce, persistent discrimination, or other serious events, but always in the context of ongoing, supportive relationships with adults. Indeed, the presence of supportive adults who create safe environments that help children learn to cope with and recover from major adverse experiences is one of the critical ingredients that make serious stressful events such as these tolerable. In some circumstances, tolerable stress can even have positive effects, but in the absence of

supportive relationships, it also can become toxic to the body's developing systems.

**Toxic stress** refers to strong, frequent, or prolonged activation of the body's stress management system. Stressful events that are chronic, uncontrollable, and/or experienced without children having access to support from caring adults tend to provoke these types of toxic stress responses. Studies indicate that toxic stress can have an adverse impact on brain architecture. In the extreme, such as in cases of severe, chronic abuse, especially during early, sensitive periods of brain development, the regions of the brain involved in fear, anxiety, and impulsive responses may overproduce neural connections while those regions dedicated to reasoning, planning, and behavioral control may produce fewer neural connections. Extreme exposure to toxic stress can change the stress system so that it responds at lower thresholds to events that might not be stressful to others, and, therefore, the stress response system activates more frequently and for longer periods than is necessary, like revving a car engine for hours every day. This wear and tear increases the risk of stress-related physical and mental illness later in life.[1]

# What Science Tells Us

THE CAPACITY TO DEAL WITH STRESS IS controlled by a set of interrelated brain circuits and hormone systems that are specifically designed to respond adaptively to environmental challenges. When an individual is threatened, this system sends signals to the brain that trigger the production of brain chemicals, as well as stress hormones that are sent throughout the body and cue the brain to prepare the individual to respond adaptively to threat.

**A poorly controlled response to stress can be damaging to health and well-being if activated too often or for too long.**

**The neural circuits for dealing with stress are particularly malleable (or "plastic") during the fetal and early childhood periods.** Early experiences shape how readily these circuits are activated and how well they can be contained and turned off. Toxic stress during this early period can affect developing brain circuits and hormonal systems in a way that leads to poorly controlled stress response systems that will be overly reactive or slow to shut down when faced with threats throughout the lifespan.[2,3] As a result, children may feel threatened by or respond impulsively to situations where no real threat exists, such as seeing anger or hostility in a facial expression that is actually neutral, or they may remain excessively anxious long after a threat has passed.

**Well-functioning brain systems that respond to stress are essential to healthy development.** The ability to cope with novel and/or potentially threatening situations, such as an unfamiliar environment or physical danger, is essential to survival. Equally essential is the body's ability to react to such things as lack of adequate nutrition, wounds, infections, and other threats or injuries. The capacity to react to both psychological and physical threats is built into specific brain circuits whose development is influenced by multiple experiences beginning early in life. However, like the immune system, a poorly controlled response to stress can be damaging to health and well-being if activated too often or for too long.[4]

**Frequent or sustained activation of brain systems that respond to stress can lead to heightened vulnerability to a range of behavioral and physiological disorders over a lifetime.** These undesirable outcomes can include a number of stress-related disorders affecting both mental health (e.g., depression, anxiety disorders, alcoholism, drug abuse) and physical health (e.g., cardiovascular disease, diabetes, stroke).[4]

**Stress responses include activation of a variety of hormone and neurochemical systems throughout the body.** Two hormonal systems have received extensive attention in this regard: (1) the sympathetic-adrenomedullary (SAM) system, which produces adrenaline in the central part of the adrenal gland, and (2) the hypothalamic-pituitary-adrenocortical (HPA) system, which

produces cortisol in the outer shell of the adrenal gland.[4] Both adrenaline and cortisol are produced under normal circumstances and help prepare the body for coping with stressors.

- **Adrenaline production occurs in response to many forms of acute stress.** It mobilizes energy stores and alters blood flow, thereby allowing the body to effectively deal with a range of stresses. Its release is essential to survival.[5]

- **Cortisol also is produced in response to many forms of stress, and likewise helps the brain and body cope effectively with adverse situations.** When it is released suddenly and turned off quickly, cortisol mobilizes energy stores, enhances certain types of memory, and activates immune responses. If the body fails to shut off the cortisol release or experiences chronic stress, longer-term effects can include suppression of immune function, other types of memory, and contributions to metabolic syndrome, bone mineral loss, and muscle atrophy.[5]

**Sustained or frequent activation of the hormonal systems that respond to stress can have serious developmental consequences, some of which may last well past the time of stress exposure.** When children experience toxic stress, their cortisol levels remain elevated for prolonged periods of time. Both animal and human studies show that long-term elevations in cortisol levels can alter the function of a number of neural systems, suppress the immune response, and even change the architecture of regions in the brain that are essential for learning and memory.[6,7]

Scientific knowledge on the effects of stress comes from research on both humans and animals, creating a combined body of knowledge that is greater than would otherwise be possible. Specifically, research involving animals informs much of what we know about the effects of stress on the developing brain architecture, including the following:

**Stress turns some specific genes "on" and others "off" at particular times and locations in the brain, and cortisol plays a key role.[8]** Examples include regulation of the glucocorticoid receptor gene, which affects the long-term responsiveness of the brain to stress-induced cortisol release, neurotrophic receptor genes that help to alter neuronal architecture, and the myelin basic protein gene, which is involved in regulating the development of the "insulation" on a nerve that increases the efficiency of signal transmission.[9,10,11] Thus, chronic stress can potentially affect the expression of genes that regulate the stress response across the life course.

**Sustained activation of the stress response system can lead to impairments in learning, memory, and the ability to regulate certain stress responses.** In both young and adult animals, high, sustained levels of cortisol or corticotropin-releasing hormone (CRH), which is the brain chemical that regulates the HPA system, result in damage to a part of the brain called the hippocampus. This area of the brain is critical to both learning and memory as well as to some types of stress response regulation.[12]

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**Significant maternal stress during pregnancy and poor maternal care during infancy both affect the developing stress system in young animals and alter genes that are involved in brain development.** Pregnant female rodents who experience exceptionally high levels of stress have offspring that are more fearful and more reactive to stress themselves. Young animals that experience inattentive maternal care have similar problems and show impaired production of neural growth factors important for brain development and repair.[13,14] Both groups of animals also have impaired memory and learning abilities, and they experience more aging-related memory and cognitive deficits in adulthood.[4,15]

**Positive experiences after infancy in young animals, such as being exposed to an environment rich in opportunities for exploration and social play, have been shown to compensate to some degree for the negative behavioral consequences**

**of prenatal stress and postnatal neglect.** This compensation actually involves adaptive changes in both the architecture and the chemistry of the developing brain (such as reversal of the effects of mild adversity on stress hormone output). However, the brain is not infinitely plastic. Some stress-related changes (e.g., reduced glucocorticoid receptors in the hippocampus) are more resistant to reversal over time.[16]

**Individual responses to early stressful experiences can vary dramatically.** This variability is thought to be related to differences among animals in the expression of so-called "vulnerability genes," which make it more likely that early stressors will lead to subsequent problems in stress hormone regulation and behavioral difficulties. In such cases, positive early caregiving can decrease the likelihood of these adverse outcomes, demonstrating that beneficial environmental influences can moderate the impact of genetic vulnerability.[17]

**The relationships children have with their caregivers play critical roles in regulating stress hormone production during the early years of life.**

Building on the animal research, studies of children living in adverse conditions are beginning to document a compelling story about the relation between early stress experiences and human development. The following findings appear to be particularly salient:

**The relationships children have with their caregivers play critical roles in regulating stress hormone production during the early years of life.** Those who experience the benefits of secure relationships have a more controlled stress hormone reaction when they are upset or frightened. This means that they are able to explore the world, meet challenges, and be frightened at times without sustaining the adverse neurological impacts of chronically elevated levels of hormones such as cortisol that increase reactivity of selected brain systems to stress and threat. In contrast, children whose relationships are insecure or disorganized demonstrate higher stress hormone levels even when they are mildly frightened. This results in an increased incidence of elevated cortisol levels, which may alter the development of brain circuits in ways that make some children less capable of coping effectively with stress as they grow up.[3]

**Research has shown that the presence of a sensitive and responsive caregiver can prevent elevations in cortisol among toddlers, even in children who tend to be temperamentally fearful or anxious.[18]** Thus, sensitive and responsive caregiving from a parent or a child care provider can serve as a powerful buffer against stress hormone exposure, even in children who might otherwise be highly vulnerable to stress-system activation.

**The quality of the early care and education that many young children receive in programs outside their homes also plays an important role in whether (and to what extent) their brains are exposed to elevated stress hormones early in life.** Young children who spend significant amounts of time in poor-quality child care settings with large ratios of children to adults, less supportive relationships, and more harsh adult-child interactions show larger elevations than those in better quality care.[19] Young children who are temperamentally shy may be in particular need of highly supportive child care; one study has shown that when these children experience child care that elevates stress hormones, they develop more symptoms of emotional problems than do outgoing children.[20]

**Children who grow up in conditions of economic hardship often exhibit elevated stress hormone levels.** This is especially true for children who live in chronic situations of poverty and experience an accumulation of adverse conditions (e.g., overcrowding, noise, substandard housing, separation from parent(s), exposure to violence, family turmoil). Moreover, the impact of economic hardship on children's stress systems is often exacerbated when mothers experience symptoms of depression.[21,22,23] Recent research also has demonstrated that a mother's depression during her child's early years increases the child's cortisol reactions to adverse family conditions later in childhood. [24,25,26]

**Young children who are neglected or abused have abnormal patterns of cortisol production that can last even after the child has been moved to a safe and loving home.**[27,28] This is especially true for children who show symptoms of post-traumatic stress, even if their behavior is not sufficient to warrant a definitive diagnosis of post-traumatic stress disorder.[29,30,31] Many maltreated children also have elevated blood pressure by adolescence and increased levels of inflammation in the blood by early adulthood, both of which increase the risk of cardiovascular disease. Intervening early to prevent maltreatment can reduce both stress hormone elevations and their associated disruptions of stress response systems.[32,33]

# Addressing Common Misconceptions

AS THE PUBLIC'S INTEREST IN SCIENTIFIC information about the development of young children is stimulated by exciting new findings, the risk of exposure to misleading or, frankly, irresponsible messages grows. Within this context, it is essential that we distinguish scientific fact from popularly accepted fiction.

**Science does not support the claim that infants and young children are too young to be affected by significant stresses that negatively affect their family and caregiving environments.** To the contrary, human studies with infants and children as well as animal studies have shown that adverse early infant experiences (e.g., neglectful maternal care) and serious disruptions of the prenatal environment (e.g., drug and alcohol exposure) can lead to short-term neurobehavioral and neurohormonal changes in offspring that may have long-term adverse effects on memory, learning, and behavior throughout life.[34]

**Notwithstanding the preceding statement, there is no credible scientific evidence that supports the conclusion that all young children who have been exposed to significant early stresses will always develop stress-related disorders.** In both animal and human studies, interventions that provide consistent, predictable, and nurturing care help to stimulate positive adaptation and prevent poor outcomes.[16,27,35]

# The Science-Policy Gap

ALTHOUGH IT IS WELL KNOWN THAT MANY young children are exposed to significant adversity, the degree to which children's early experiences influence their biological responsiveness to later stress is not broadly understood. Evidence that stresses experienced by parents and other caregivers can affect a child's developing brain architecture and chemistry in a way that makes some children more susceptible to stress-related disorders later in life is also new information for most people.

A rich and growing scientific knowledge base illuminates the multiple adverse effects of early life stresses, including their long-term impacts on children's ability to learn, adapt, and cope with stress throughout their lives. Yet little attention has been paid to the development and implementation of strategies to prevent or reduce significant stressors that affect children and families every day. This gap between what we know about the potentially harmful developmental impacts of adversities experienced by both caregivers and children, and what we do to promote healthy coping and adaptation through informal supports, voluntary workplace practices, and formal public policies and programs, is illustrated by the following examples:

**Limited availability of family leave after the birth or adoption of a baby, and little financial support for parents who wish to stay at home with their newborns but do not have the economic resources to make ends meet in the absence of**

**paid employment.** In some circumstances, this creates situations where the supportive relationships necessary to help very young children manage stress are intermittent or seriously compromised.[36,37,38,39]

**Limited availability of convenient, affordable, high-quality early care and education, flexible scheduling options for jobs and health care, and community-based support for working parents at all income levels who are struggling to balance the demands and responsibilities of work and raising children.** These balancing challenges are particularly difficult for low-income, working families whose economic security depends on multiple low-wage jobs, often during non-standard working hours, and for families whose children have chronic health problems or special developmental needs that require multiple medical appointments and specialized child care. In such circumstances, some young children are subjected to excessive stress that can have lasting effects on their health and well-being.[35]

**Limited efforts to reduce high job turnover in child care programs, which affects the quality of relationships between adults and the children under their care.** This is a particularly serious problem for those children whose family's socioeconomic circumstances limit their access to better-quality programs that have staffs that are well trained, adequately compensated, and more stable.[39,40,41,42]

**Limited availability of expert help and promising interventions for parents and providers of early care and education who are struggling to manage behavioral difficulties in young children.** Recent data on increases in the expulsion of children from preschool programs indicate the extent to which staff members are unable and/or unwilling to deal with challenging behavioral problems.[43] The growing "off-label" use of prescription drugs, particularly stimulant and anti-depressant medications, for increasingly younger children with emotional or behavioral difficulties is another sign of the extent to which parents are putting greater pressure on professionals to provide more help in managing behavior problems during the preschool years.[44]

**Limited access to clinical expertise in mental health for very young children and their families.** This is particularly problematic in child welfare agencies that are mandated to assess children who are coping with toxic stress that can have lasting adverse effects on their well-being. In this context, young children who experience debilitating anxiety and trauma as a result of abuse or neglect, or those who witness violence in their family or neighborhood, would derive substantial benefits from specialized treatment, beginning as early as possible.[45,46]

# Implications for Policy and Practice

THE SCIENCE OF EARLY CHILDHOOD DEVELOPMENT, including knowledge about the impact of stress on the developing brain, supports a number of evidence-based implications for those who develop and implement policies that affect the health and well-being of young children.[47,48] To this end, both public policy and private-sector actions can prevent the kinds of adverse circumstances that are capable of derailing healthy development, as well as increase the likelihood that effective interventions will reduce potential damage to a young child's developing brain architecture and thereby promote greater resilience. The following six implications are particularly worthy of thoughtful consideration.

**The scientific understanding of how children cope with stress should be used to strengthen a range of informal supports and formal services to bolster parents who are struggling to manage the challenges of raising their children.** These could be provided through varying combinations of extended family support, community-based volunteer efforts, flexible workplace policies, and publicly funded programs.[49]

**High-quality early care and education programs that provide stable, supportive relationships with caring adults should be more available to young children who are at risk of experiencing tolerable or toxic stress.** Extensive research evidence

underscores the particular importance of higher-quality programs for young children who are temperamentally vulnerable to fear and anxiety. Assuring that a young child has reliable, safe, and engaging relationships both at home and in out-of-home care can buffer the effects of multiple stressors that may exist in his or her life.

**Affordable expert assistance should be more available to parents, relatives, foster parents, teachers, physicians, caseworkers, and providers of early care and education who do not have sufficient knowledge and skills to help young children who exhibit symptoms related to abnormal stress responses.** This is particularly important for children who exhibit excessive fears, aggressive behavior, or difficulties with attention and "hyperactivity."[39,45]

**Existing intervention programs could better address the effects of toxic stress if they incorporate training and expertise in the identification of young children with serious, stress-related, mental health problems (as well as mothers with depression) and have ready access to expert assessment and mental health services as needed.** Research indicates that young children can experience a range of mental health impairments that used to be viewed solely as adult problems, such as depression, anxiety disorders, and anti-social behaviors.[39] Pediatric practitioners must also be trained to understand and identify the signs of early adversity and toxic stress in childhood as a strategy to prevent adult diseases later in life.[50,51] All professionals who interact with children on a daily basis are best positioned to learn from—and inform—science-based strategies that prevent and address the impacts of toxic stress early in life.[50,52]

**Responses to suspected child abuse or neglect should include an expert assessment of the child's developmental status, including cognitive, linguistic, emotional, and social competence.** This could be accomplished through closer collaboration between child welfare services and early intervention programs for children with developmental delays or disabilities,[53] as mandated by the Keeping Children and Families Safe Act of 2003 and the more recent reauthorization of the Individuals with Disabilities Education Act (IDEA), or through Medicaid's Early and Periodic Screening, Diagnostic, and Treatment (EPSDT) benefit.

**Because families experiencing poverty are likely to have greater exposure to stress and fewer resources to deal with adversity than the general population, adult-focused services in the Temporary Assistance for Needy Families (TANF) program should be augmented to include developmental screening assessments for their children.** In this context, it is difficult to justify the extent to which public discussion about support for low-income parents focuses primarily on maternal employment and other adult behaviors, while the specific needs of the young children in these families are afforded relatively little attention. Our knowledge of the importance of supportive relationships as buffers against the adverse effects of stress on the architecture of the developing brain indicates the need for serious reconsideration of mandated employment for mothers of very young children, particularly when access to high-quality child care is not assured. Research also underscores the importance of timely assessments and intervention services (when indicated) for children living in stressful environments who show early signs of developmental difficulties.[54,55]

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