# Early Adversity, Cognition, and Intervention


## Abstract

43.5 million U.S. residents currently live in poverty, and many will continue to live in poverty for the rest of their lives. One factor contributing to this phenomenon is the attenuated cognitive development experienced by infants growing up in poverty. Infancy is a critical period of development, so the conditions that infants are exposed to have the ability to change the development of their brains and impact later behavior in adulthood. Individuals raised in poverty are exposed to an excess of stressful stimuli, and do not receive as much attention and enrichment from parents as do children of high socioeconomic status (SES). Animal studies show that adequate maternal care has the ability to normalize the stress-response of individuals born with a genetic tendency to high stress, or born into a stressful environment. Additionally, breast feeding and direct parent-child talk has a positive impact on childhood cognitive development and language abilities. Government interventions at both the family and the school level may have the ability to nurture those growing up in poverty, so that their cognitive functioning will not be negatively impacted by adverse living conditions.

**Introduction**

Approximately 45.3 million U.S. residents currently live in poverty (Poverty Facts, 2015). The government defines poverty based on the ration of household income to the number of people that the household contains. For families of four, poverty is defined by a yearly household income of $23,550 or less (2013 Poverty Guidelines, 2015). Broken down, this indicates that individuals living below the poverty line must subsist on $16 or less per day. Poverty is associated with various dangerous health risks. According to Gallup polls, individuals living in poverty experience higher rates of disease than the rest of the population. Individuals living under the poverty threshold often suffer from hunger and over-crowded living conditions. While the impoverished experience diabetes, obesity, asthma, and high blood pressure at rates that are only marginally higher than average, a greater discrepancy is seen in depressive disorders, as twice as many impoverished individuals than non-impoverished individuals report having struggled with depression (Brown, 2012).

A disproportionate number of children are affected by poverty. While 14.5% of the U.S. population subsists under the poverty line, 19.9% of U.S. children live in poverty (Poverty Facts, 2015). While the health of all individuals can be negatively impacted by poverty, children take the hardest blow. Because childhood contains sensitive periods that are crucial for development, the negative events that children experience have more impact than they would have on adults (Knudsen, 2004). For example, children whose mothers were undernourished during pregnancy develop heads that are smaller than average (Gale et. al., 2004). This small head size is associated with cognitive deficits, as these children

show lower IQs at age nine than individuals with average-sized heads, whose mothers were well-nourished during pregnancy (Gale et. al., 2004).

Research shows that the development of individuals' stress response is also highly contingent upon the care that they receive at an early age. Those who do not receive adequate physical and emotional care as children often exhibit an over-active stress response and have trouble with emotion regulation (Blair & Raver, 2012). However, the development of behavior is an interactive process, and outcomes are also contingent on the genes that individuals are born with (Wang et. al., 2011). Breast-feeding, parental wellbeing, and conversation in the home are three elements that, when present or absent, can influence the way in which children develop (Anderson, Johnstone, & Remley, 1999; Evans, Maxwell, & Hart, 1999; Cogill et. al., 1986). Research shows that individuals living in poverty often experience the aforementioned deficits in care.

In this paper, I will first review the neural mechanisms that cause infants to be over sensitive to aversive conditions. Then, I will discuss specific environmental situation associated with poverty, and explain why they lead to deficits in children's development. Finally, I will give an overview of various interventions that have been successful in shielding low-income family environments from halting the development of their children.

## Literature Review

### *Infancy and Critical Periods*

In order to understand why infancy is so important to the development of the adolescent and adult brain, it is important to first gain an understanding of sensitive and critical periods. When the effect of experience is particularly strong during a period of

development, that period is referred to as a sensitive period (Kandel et. al., 2013). During sensitive periods, experience has a greater ability to instruct the development of neural circuits. In other words, the architecture of an individual's neural circuits will develop in a way that is adaptive to whichever conditions an individual is experiencing during the sensitive period (Kandel et. al., 2013). Further, when the changes made during this period have the ability to affect later adult behavior, that period is referred to as a *critical period* (Knudsen, 2004). Critical periods for different behaviors differ, but it is known that infancy is a critical period for many behaviors, including the stress response (Kandel et. al., 2013).

At the neuro-anatomical level, critical periods refer to moments in time when an organism's brain is highly plastic, and neurons are actively growing to make new connections while other connections are being eliminated. Figure 1 provides three different examples of synaptic refinement, including the development of a new axonal projection field via learned experience, elimination of dendritic spines that have been unused, and consolidation of synapses (Figure 1). All three of these events are emblematic of permanent learning occurring during the sensitive period (Knudsen, 2004).

The importance of critical periods in development has been established by both human and animal studies. For example, starvation only has stunting effects on the size of adult rats when it occurs during infancy (Dobbing, 1976), and individuals rescued from the harsh conditions of Romanian orphanages showed better developmental outcomes when they were rescued at an earlier age, as they were able to spend a greater portion of their critical period in enriched conditions than those who were rescued later (Gunner, Morison, Chisholm, Schuder, 2001). Since infants are generally in the care of their parents during

this period, it is important to examine how early parental care affects development and later behavior.

*The Stress Response and Cognition*

The development of the stress response is especially important for later cognitive development. Individuals with an overactive stress response have higher circulating levels of cortisol, a stress hormone that has a direct negative effect on learning and memory (Wolf, 2003). Kirschbaum et al. conducted an experiment in which they exposed human subjects to brief, psychosocial stressors, and measured levels of cortisol in their blood afterward. Results showed that individuals with higher levels of cortisol (high reactivity), experienced greater deficits in recall of declarative memories (Kirschbaum et. al., 1996). Additionally, de Quervain et. al. found that cortisol impairs recall of words that were learned 24 hours earlier (de Quervain et. al., 2009). Thus, an overactive stress response, which leads to high levels of cortisol, has the ability to impair learning, memory, and cognition. All of these processes are important for success in both school and 21st century life, and may be important to the exacerbation of the poverty cycle.

*Animal Models of Early Maternal Care*

The development of the stress response in rats is highly contingent upon the maternal care that they receive during the critical period of infancy. Past studies have shown that rats raised by mothers exhibiting a high frequency in licking and grooming behavior (high LG) had attenuated stress responses compared to those who are raised by mothers who exhibited less frequent licking behavior (low LG) (Meaney, 2001).

Furthermore, rats born to low LG mothers but raised by high LG mothers exhibited stress-responses similar to those of rats that were genetically related to high LG mothers (Meaney, 2001). The opposite of this was true as well; rats born to high LG mothers but raised by low LG mothers showed stress responses similar to those of their foster mother, rather than their biological mother (Liu et. al., 2000).

Additionally, other studies show that maternal licking and grooming behavior increases glucocorticoid receptor (GR) gene expression. GRs are cortisol receptors that mediate intracellular responses to circulating cortisol, thus returning the body to a normal state when it has been flooded with stress-related hormones. When GR levels are decreased, this negative feedback is weakened, leading the stress response to be longer lasting and more severe (Kandel et. al., 2013). Individuals born to high LG mothers expressed higher GR levels, higher GR mRNA levels, and hypomethylation of the $I_7$ GR promoter sequence in the hippocampus (Figure 2). Hypomthylation is correlated with increased gene expression, so hypomethylation of the GR $I_7$ promotor in high LG offspring may be responsible for the increased GR expression and efficient stress-regulation (McCormick et. al., 2000).

In a later study, Meaney and colleagues sought to test this hypothesis (Weaver et. al., 2004). Experimenters first examined the methylation of the $I_7$ exon of both low LG and high LG offspring. In congruence with previous research, they found that low LG offspring showed significantly greater methylation at the $I_7$ 5'CpG dinucleotide than the high LG offspring (Weaver et. al., 2004). In order to test the sufficiency of methylation at this specific site to cause decreases in GR levels, investigators used a viral vehicle to decrease methylation in low LG individuals. They found that the alteration of methylation at this

single promoter was sufficient to change the behavior of low LG individuals to resemble the behavior of high LG individuals. Additionally, they found that cross-fostering low LG offspring with high LG mothers had the ability to change the methylation of the $I_7$ promoter. Therefore, it is likely that this specific piece of mRNA is a crucial element to establishing methylation in offspring, GR action, and ultimately, the stress response (Meaney et. al., 2004).

*The Human Paradigm*

While humans do not lick their offspring, breast-feeding seems to be an analogous behavior due to the intimacy and skin-to-skin contact that it provides. In a meta-analysis assessing the effects of breast-feeding on cognitive development, researchers found that children who were breast-fed consistently showed higher scores of cognitive development than children who were not breast-fed (Anderson, Johnstone, & Remley). Cognitive development was measured through various credible tests, including the Stanford-Binet Intelligence Scale and the Peabody Picture Vocabulary Test. It is still not understood how breast-feeding improves cognitive development, but it may be possible that close touching by mothers leads to the demethylation of the $I_7$ portion of the GR mRNA in the same way that it does in rats.

Breast-feeding is an important element to consider when examining the developmental effects of poverty, because low SES mothers are less likely to breast-feed than middle and high SES mothers (Heck et. al., 2006). In fact, research shows that mothers living below the poverty line are three times as likely as wealthy mothers to report never having breast-fed their children. There are multiple factors that likely contribute to this

statistic: First, low SES mothers are, on average, less educated than high SES mothers. The same study showed that educational status is also highly correlated with breast-feeding efficacy, with four times as many high school dropouts reporting never breast-feeding compared to their college educated counterparts. Mothers working blue-collar jobs are also less likely to breast feed. Not only do low SES mothers often work blue-collar jobs, but they are also less highly educated. Thus, it makes sense that low SES mothers are less likely to breast-feed (Heck et. al., 2006). Since these mothers may not have been educated about the benefits of breast-feeding and may not have the privilege of receiving maternity leave through their employers, they are less likely to breast-feed (Bertini et. al., 2003).

*Beyond the Mother*

In addition to direct contact from the mother, a child's living situation also has the ability to impact cognitive development. Of the individuals in the United States living in poverty, 6% also live in over-crowded homes (Understanding Poverty, 2014). This means that 2.7% of U.S. residents suffer from both deficits in money and deficits in living space. Many studies have investigated the effect of growing up in crowded houses on cognitive development. Over-crowding is considered to be a chronic stressor, so growing up in a crowded home likely increases individuals' stress response, therefore stymying their later cognitive development (Stress, 2013). More specifically, research shows that crowded homes raise children with attenuated language skills (Evans, Maxwell, & Hart, 1999).

In 1999, Evans, Maxwell, and Hart examined the parental language and verbal responsiveness of parents in over-crowded homes. They found that, compared to un-crowded homes, these parents did not speak less, but rather spoke in less complex

sentences (Evans, Maxwell, & Hart, 1999). Additionally, they were less verbally responsive to the needs and emotions of their children. The lack of complexity and responsiveness visible in parents living in over-crowded households was reflected in their children's use of language. As a result of their environment, these children spoke in less complex sentences than children raised in less crowded households (Evans, Maxwell, & Hart, 1999). The combination of less engaged parents and high levels of stress experienced by these impoverished children probably play a role in the educational under-achievement of low SES children (Morgan, Farkas, Hillemeier, & Maczuga, 2009), and resulting difficulty in attending college and finding a job.

*Intervention*

In 1965, President Lyndon Baines Johnson created a new political agenda, which he titled "The War on Poverty". This agenda sought to decrease the poverty rate in the United States, and included various programs to help increase education and health among the poor (Lyndon Baines Johnson, 2015). One of the programs included within this agenda was "Head Start", an initiative created to help educate and support new parents and provide an enriched pre-school experience to low SES kids. A study published in 2005 evaluated the efficacy of the Head Start program in 3-year old children (Love et. al., 2005). Researchers used a sample of 3,001 families from 17 different Head Start Programs, and conducted interviews with primary caregivers, observed parent-child interactions, and evaluated children through cognitive tests (Love et. al., 2005). Results showed that the kids who had gone through the Head Start program displayed greater language and cognitive development, higher social engagement, and less aggressive behavior than those who did

not attend the Head Start program (Love et. al., 2005). Additionally, the parents of Head Start infants were more emotionally supportive, spanked less, and provided more language and learning stimulation than parents who had not been through the program (Love et. al., 2005). Results from this study demonstrate the importance of early education when seeking to stem the negative effects of poverty on children's development.

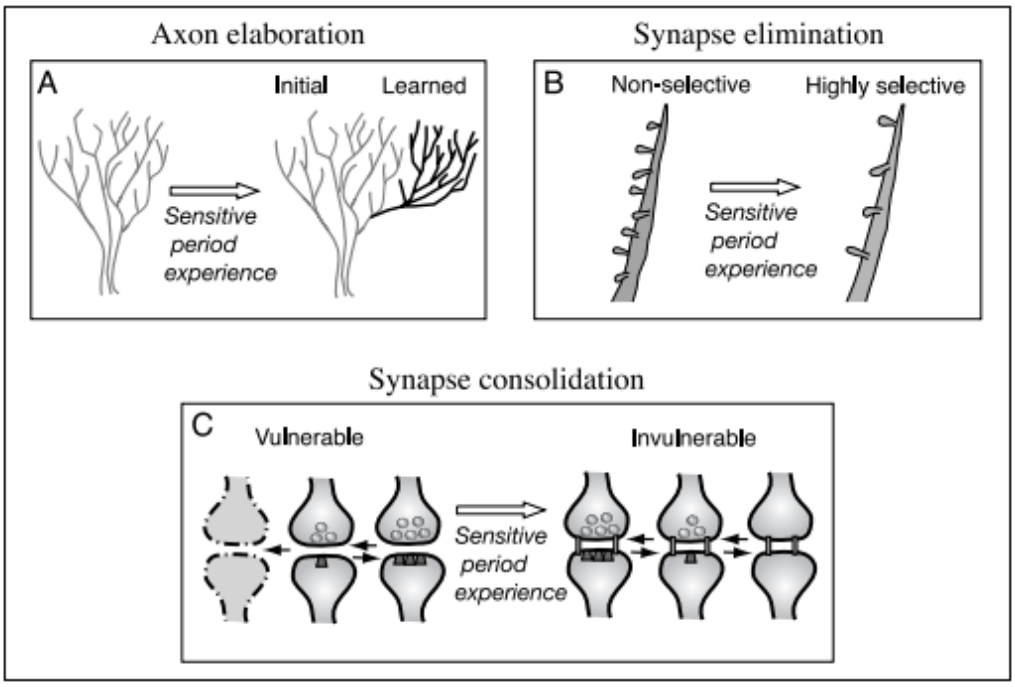
**Discussion**

Both animal and human studies consistently show that stress has a negative effect on development. In the context of human behavior, stress often causes deficits in learning and memory. Since learning and memory are important in both work and school settings, individuals who have experienced increased stress and blood-cortisol levels from a young age may have trouble thriving in these domains. Furthermore, individuals raised in poverty are often exposed to more stressors and receive less enriching care as infants, and the combination of an overactive stress response and learning deficits may play a role in exacerbating the poverty cycle. When individuals born into poverty are unable to succeed in school and in the job market, they are also unable to acquire enough resources to help the next generation escape the situation that they were born into themselves.

Recent animal studies show that the $I_7$ promoter of glucocorticoid receptor mRNA may be responsible for genetically based responses to stress (Weaver et. al., 2004). Meaney et. al. found that individuals raised by high licking-grooming mothers both showed a normal stress response and decreased methylation of this portion of mRNA. On the other hand, mice raised by low licking-grooming mothers showed both an overactive stress response and greater methylation of this gene. However, when rats born to low LG mothers

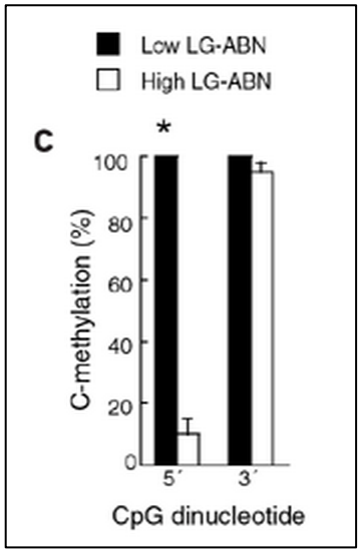
were raised by high LG mothers, the methylation of the $I_7$ portion decreased over time (Weaver et. al., 2004). This shows that, while genetics have an effect on the stress response, maternal behavior has the ability to epigenetically alter gene expression. Similar studies have been performed using humans, and they have shown that childhood abuse is correlated with both an overactive HPA axis and increased methylation of the $I_F$ promoter of glucocorticoid receptor mRNA (McGowan et. al., 2009). The consistency between Meaney and McGowan's findings implies that future research should be done to examine how identifying and changing the methylation of these genes could be useful in attenuating the stress response of those who are born naturally anxious or who experience adverse conditions at a young age.

Since the prospect of both understanding exactly how glucocorticoid mRNA affects the stress response and developing therapies to change gene expression in humans is still far off, other strategies must be utilized to help alleviate poverty's impact on stress and cognition. while the government has already created community initiatives such as Head Start, more family-friendly policies must be implemented. Currently, only 11% of U.S. employers supply employees with some sort of paid maternity leave. However, in our nearest neighbor Canada, mothers are provided with between 21 and 52 weeks of maternity leave (Rosen, 2014). Increasing the amount of required paid maternity leave in the United States would allow mothers who normally cannot afford it to breast-feed and engage with their children, which would have the ability to improve their cognitive outcomes.




*A. The development of a new axonal projection field via learned experience*
*B. The elimination of dendritic spines that have been unused*
*C. Shows the consolidation of synapses (Knudsen, 2004)*

2.




*The left column shows the increased methylation of part of the $I_7$ glucocorticoid receptor mRNA in low LG offspring.*
*Abbreviations: LG = licking and grooming; ABN = arched back nursing (Weaver et. al., 2004)*

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