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Childhood Poverty and Its Effects on the Brain: Physiological and Functional Implications

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ABSTRACT

One out of every five American children lives below the federal poverty line. Considering that poverty is deemed one of the most influential risk factors for poor developmental outcomes, it is critical to understand what effect poverty has on the developing brain and how those brain changes affect a child's life. Poverty is chiefly defined by having a low socioeconomic status (SES), but a low SES is often accompanied by other influencers, such as nutrition and mental stimulation, termed poverty co-factors. Other poverty co-factors include, but are not limited to, maternal stress and malnutrition, environmental toxins, parental nurturance, and education.

A low SES and accompanying poverty co-factors influence changes in the brain, including both the type and rate of change. Variances have been noted in the frontal lobe, prefrontal cortex, amygdala, hippocampus, and the white and grey matter size and ratios. Neurotransmitter and hormone modifications have also been observed. These brain changes have long-reaching impacts, affecting educational and intellectual attainment, emotional processing, and risk of mental illness.

As knowledge regarding poverty-driven brain changes increases, more possible intervention strategies are being developed. These strategies center on parental involvement and mental and verbal stimulation. The achievement discrepancies noticed between children raised below the poverty line and children raised above it likely contribute to the continuation of intergenerational poverty. Further research and information regarding poverty and how it affects the developing brain contribute to developing target strategies to ameliorate the effects of childhood poverty.

INTRODUCTION

Childhood poverty is one of the most dominant and powerful risk factors for poor developmental outcomes. Approximately 21% of all children living in the United States live in poverty, with their families making incomes below the federal poverty threshold. When one considers that families need an income of about twice that given in the federal poverty threshold in order to cover basic expenses, that percentage rises to 43% of children living in poverty.[1] The National Center for Education Statistics brings this percentage even higher to 51% of children living in low-income families.[12] In 2016, the federal poverty threshold was set at an income of $24,339 a year for a family of four with two children. As previously mentioned, it has been suggested that families need an income closer to two times that laid out by the federal poverty threshold. Taking this into account, families of four with a yearly income less than $48,678 are defined as low income.[3]

Children raised in poverty are more likely to have decreased intellectual and educational achievement compared to their peers. Childhood poverty also results in poor cognitive outcomes and a higher risk of mental illness.[4] The level of poverty at which a child is raised correlates with their school readiness skills[2] as well as their abilities in regard to executive functioning.[5] Chronic poverty and familial financial conflict are predictive of children's performances on executive functioning measurements.[5] A low socioeconomic status (SES) is responsible for around 20% of the variances in childhood IQ. Reduction in IQ points due to a low SES can be seen by age five.[4] Not only does poverty affect areas such as school readiness, executive functioning, and IQ while the child is in poverty, childhood poverty also influences educational attainment, health, and

psychological well-being far into adulthood.[6] Children who are raised in poverty are at a higher risk for developing a myriad of mental illness in adulthood, including depression and signficiant antisocial behaviors. A low SES is not the only factor to blame for these outcomes. Risk factors that often accompany a low SES, such as poor nutrition, pollution, and parental conflict, also play a role in poor developmental outcomes. In this paper, these risk factors will be referred to as poverty cofactors. The effects poverty has on the development brain are far from inconsequential and could contribute to the continuation of intergenerational poverty.[4]

This review attempts to provide a broad overview of poverty and its effects on the brain, including a discussion of what poverty is, structural and functional brain changes resulting from poverty, the effects of those changes, and the possible remedies and solutions for preventing poor outcomes resulting from variances in the brain. Childhood poverty, defined as a low familial socioeconomic status, along with poverty cofactors affect many areas of the brain including the frontal lobe, the prefrontal cortex, the amygdala, and the hippocampus. Neurotransmitter and hormone and white and grey matter changes are also observed. The changes of these brain structures have long-term effects on memory, educational and intellectual achievement, and emotional processing. These effects can be partially mitigated by parental involvement and mental and verbal stimulation.

PRENATAL INFLUENCES

Poverty begins influencing a child even before birth. The impacts of maternal stress and maternal malnutrition greatly impact a child's development. These effects are so strongly linked to poor

birth outcome that prematurity and growth restriction can be used as indicators of prenatal adversity.[7] Types of maternal stress include physiological stressors such as inflammation as well as psychosocial stress. Repeated exposure to these stressors, especially psychosocial stress, may negatively impact women's immune, endocrine, and reproductive systems, possibly impacting the health of their children.[8] These maternal stressors lead to an overall increase in poor birth outcome in low SES families. During times of prenatal adversity, blood is shunted from peripheral organs to the central nervous system, but only partial fetal protection is achieved. This leads to fetal growth restriction, which has been shown to be correlated with ADHD and depression in both adolescence and adulthood.[7] It has been observed that women with a low SES are more likely than women with a moderate or high SES to deliver babies that are underweight or premature. A low birth weight is indicative of obesity, type two diabetes mellitus, and hypertension in adulthood. A low birth weight and fetal growth restriction caused by maternal stress tend to increase in prevalence with increasing maternal age. However, younger mothers are more likely to experience higher levels of psychosocial stress and social disadvantage. Younger mothers are also more likely to use illicit substances,[8] such as methamphetamine. Methamphetamine use is the most commonly cited primary drug problem among pregnant women. Areas where methamphetamine use is already prevalent, such as areas characterized by residents with a low SES, will see increased use of methamphetamines by pregnant women as compared to areas without high methamphetamine use. Prenatal methamphetamine exposure leads to increased displays of aggression, behavioral dysregulation, and difficulties in executive functioning in children.[9]

Maternal malnutrition, including nutrition deficiencies and obesity, also influences birth outcomes. Folate, choline, B12, zinc, omega-3 fatty acids, iodine, and iron deficiencies are commonly noted in pregnant women living in poverty. Folate, choline, and B12 deficiencies can lead to neural tube defects such as spina bifida in a folate deficiency. Choline deficiencies can lead to oral-facial clefts in the newborn. Low zinc and iron levels can be responsible for a low birth weight. Decreased omega-3 fatty acid levels can lead to malignancies in fetal brain and eye development. Maternal iodine levels are responsible in part for the brain and nervous system development of the fetus.[7] Nutritional deficiencies during pregnancy can have serious effects on the developing child.

Obesity has also been observed among pregnant women with a low SES. Maternal obesity predicts many pregnancy and birth complications, including gestational diabetes and hypertension, preeclampsia, depression, greater risk of preterm birth, fetal defects, congenital anomalies, and perinatal death.[7] Preterm birth and fetal growth restriction, as mentioned above, are linked to health concerns such as obesity, hypertension, ADHD, and depression. Nutritional deficiencies and maternal obesity are associated with various pregnancy and birth complications and can result in poor birth outcomes.

FACTORS AFFECTING BRAIN DEVELOPMENT

We will now turn from looking at the effects of poverty on the prenatal brain to looking at how poverty affects the developing brain during childhood. Though there are many factors that can influence brain development, we will primarily focus on the factors that are commonly

associated with a low familial SES. It is important to keep in mind that many of the changes that will be discussed have only been observed as correlations, not causations. At the present time, many of the mechanisms behind brain changes are unknown, but have been observed to follow certain factors which will be discussed. Prominent factors affecting brain development in childhood include financial stress, environmental toxins, parental conflict, parental nurturance, level of mental and lingual stimulation, quality of education, and nutrition.

A low socioeconomic status is often indicative of financial insecurity and stress. It can be tempting to view financial stress as only affecting the breadwinners of families, but financial stress reaches widely in a family and tends to affect all members. Financial insecurity is often accompanied by other forms of insecurities, including shelter, food, and safety insecurities.[10] Chronic stress, often experienced by children living in poverty, can be measured with an index of allostatic load. This accounts for the wear and tear on the body caused by repeated mobilizations in response to environmental demands. Shelter and housing insecurities contribute to chronic stress.[11] It has been observed that lower-income families move homes often. In 2002, 6.5% of all children had been living in their homes for fewer than six months, compared to the 10.1% of low-income children having been living in their homes for the same amount of time. Over a year, the percentage of moves experienced by families living above poverty was 12.8%, while for those living below poverty the rate was 24.1%. Low-income families also experience more unplanned moves than moderate or high-income families. Most low-income moves are a result of what has been termed “push mechanisms.” Examples of these push mechanisms are foreclosures and evictions, leading to forced, involuntary, or unplanned moves. Studies have shown that frequent moves are related to reduced academic performance. Children who moved three or more

times during childhood have greater attention problems than children who did not move. In addition to greater attention problems, children living below the poverty line who move have difficulty modulating internalizing and externalizing behavior. Children who move three or more times in their early life have a 13.7% decreased chance of graduating high school.[12] The common reason behind low-income families moving because of push mechanisms is low financial stability. Additionally, it has been observed that family income moderates the relation between the brain's white matter and cognitive flexibility.[13]

Food instability is defined as the lack of consistent access to adequate food. Very low food security among children is defined as the presence of disrupted meal patterns and the intake of food that is less than the amount the children's caregivers deem adequate. In a 2012 study, 24% of low-SES households reported food insecurity among children.

18 Questions for measuring food security in the Food Security Supplement of the Current Population Survey.

1. "We worried whether our food would run out before we got money to buy more." Was that often, sometimes, or never true for you in the last 12 months?
2. "The food that we bought just didn't last and we didn't have money to get more." Was that often, sometimes, or never true for you in the last 12 months?
3. "We couldn't afford to eat balanced meals." Was that often, sometimes, or never true for you in the last 12 months?
4. In the last 12 months, did you or other adults in the household ever cut the size of your meals or skip meals because there wasn't enough money for food? (Yes/No)
5. (If yes to Question 4) How often did this happen – almost every month, some months but not every month, or in only 1 or 2 months?
6. In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food? (Yes/No)
7. In the last 12 months, were you ever hungry, but didn't eat, because there wasn't enough money for food? (Yes/No)
8. In the last 12 months, did you lose weight because there wasn't enough money for food? (Yes/No)
9. In the last 12 months did you or other adults in your household ever not eat for a whole day because there wasn't enough money for food? (Yes/No)
10. (If yes to Question 9) How often did this happen – almost every month, some months but not every month, or in only 1 or 2 months?
11. "We relied on only a few kinds of low-cost food to feed our children because we were running out of money to buy food." Was that often, sometimes, or never true for you in the last 12 months?
12. "We couldn't feed our children a balanced meal, because we couldn't afford that." Was that often, sometimes, or never true for you in the last 12 months?
13. "The children were not eating enough because we just couldn't afford enough food." Was that often, sometimes, or never true for you in the last 12 months?
14. In the last 12 months, did you ever cut the size of any of the children's meals because there wasn't enough money for food? (Yes/No)
15. In the last 12 months, were the children ever hungry but you just couldn't afford more food? (Yes/No)
16. In the last 12 months, did any of the children ever skip a meal because there wasn't enough money for food? (Yes/No)
17. (If yes to Question 16) How often did this happen – almost every month, some months but not every month, or in only 1 or 2 months?
18. In the last 12 months did any of the children ever not eat for a whole day because there wasn't enough money for food? (Yes/No)

Table 1: A list of the questions asked to low-SES families in order to determine their level of food insecurity[14]

Low-SES families were interviewed and asked a series of questions outlined in table 1. The families were then sorted into five categories: no food insecurity, marginal food security among adults and no child food insecurity, marginal food security among children, low food security among children, and very low food security among children. In the same study, it was found that the rate of food insecurity increases as the income-to-needs ratio decreases. If a family has greater need than their income can fulfill, they will have a low income-to-needs ratio and their potential for experiencing food insecurity is increased.[14]

Instability regarding safety is harder to define than housing and food instability. Some factors involved in child safety, such as child abuse and maltreatment, will be mentioned but not explained in-depth: child abuse is a very complicated topic beyond the scope of this paper. Risk factors affecting child safety include but are not limited to the following: the degree of disorder within a child's home and school,[15] parental mental illness, the threat of physical and sexual abuse, and the potential of foster care placement.[16] These risk factors all contribute to a child's feeling of safety within their environment, especially within their homes and schools. The degree of disorder or chaos within a home will be outlined in the following paragraphs. Overall, youth who feel safer at school tend to be more engaged in the classroom and with the lesson. They also demonstrate fewer depressive symptoms than students who feel unsafe at school.[17]

Residential areas characterized by low-SES residents tend to have more environmental risk factors. With increasing research being performed in the field of environmental justice, more evidence has been found that the poor, especially the non-white poor, are more likely to live in areas bearing a disproportionate amount of the burden of exposure to unhealthy environments. The environmental risk factors that the poor experience can include air and water pollution, tobacco smoke, lead poisoning[18], hazardous wastes, residential crowding, unsafe buildings, low neighborhood quality, ambient noise, and housing quality. Exposure to one factor is unlikely to have a toxic effect on health, but these environmental risk factors often accompany each other. Exposure to two or more risk factors causes changes in psychological and cognitive functioning.[19] Children living in poverty are more likely to live in neighborhoods with environmental toxins, such as lead paint, and they are more likely to experience nutritional deficits. Iron deficiencies, coupled with environmental lead, leads to lead poisoning. Lead

poisoning changes glutamate and dopamine transmission, altering neuronal plasticity and synaptic communication. These changes particularly affect the prefrontal cortex (PFC), hippocampus, and cerebellum. More information on structural brain changes will be given further on.[18] In poor areas, building safety is less likely to be regulated and enforced, leading to unsafe working conditions and educational facilities. Those living beneath the poverty line are most likely to be exposed to multiple environmental risk factors, and even moderate amounts of exposure can cause cognitive changes.[19]

Low-SES households can often be characterized as being chaotic. Background noise, such as the television and radio, is often unmonitored and conflict between members of the family can go unchecked. This chaos, background noise, and conflict contribute to the level chronic stress children experience. Elevated levels of stress hormones, such as cortisol, have been found in children living in low-SES households and even prenatally in fetuses. Chronic stress results in negative consequences cognitively, emotionally, and behaviorally.[20] Poor children often experience more violence in their homes, including domestic violence and physical and sexual abuse. Homes occupied by low-SES families are often more crowded with family members, leading to decreased one-on-one attention given to children. In addition to this increased level of stress, children living in poverty also tend to experience a decreased level of parental nurturance. Parental nurturance can include parents hugging their children, reading books to their children, and holding infants and toddlers.[2] Additionally, single-mother households encounter an economic disadvantage, as there is often only one income serving to provide for the family. Single parents are much more likely to be poor than parents who are married. Fewer resources are available to single-mother families, and they often do not have enough money for books,

clothes, and extracurricular activities. Divorce or separation in marriage has been linked to poorer child outcomes. The stress and conflict associated with divorce or separation can impair parental mental health and lower parenting quality. Parental conflict leads to dysfunctional social interactions in children, resulting in emotional and behavioral problems. Parental conflict also threatens children's academic success. Single-mother households and divorce or separation in marriage have been shown to result in poorer academic achievement and decreased social and emotional development in children. It has also been shown that it is the degree of familial instability, not structure, that results in these effects.[21]

Children raised in poverty experience less cognitive stimulation than their more advantaged peers, on average. Material deprivation can account for the lack of stimulation observed in low-SES homes. Families simply do not have the financial capability to provide their children with toys, books, educational opportunities, and novelty. Low-SES areas are often lacking in resources to provide children with cognitive stimulation, including children's museums, library book-reading programs, and parent and children groups. Because of this, children raised in these areas do not receive the social stimulation or novelty experienced by children raised above the poverty line. In this context, novelty simply means something new. This could include going on a road trip to a different city or could refer to reading a new book. In order for children to be cognitively stimulated, they must be exposed to new information in order to learn to process newness. Material deprivation accounts for some of the lack of cognitive stimulation, but other factors also come into play. Low-SES families tend to have a low language complexity. Children are not exposed to new words and their meanings. Children learn how to speak by listening to those around them have conversations with each other and with them. Poor children are often not

raised being talked to directly and learning how to speak from a parent speaking directly to them. This will slow their language-learning capabilities and exposure to novelty. The lack of cognitive stimulation experienced by children raised in poverty has been hypothesized to contribute to changes observed in prefrontal cortex function as well as deficits in various neurocognitive functions.[18]

Families living in poverty often experience an overall lack of education and a low quality of education that they do receive.

Income status of children under age 18, by parental education

	Less than High School		High School	
	Low-Income	Above Low-Income	Low-Income	Above Low-Income
National	83%	17%	66%	34%
Alaska	81%	19%*	59%	41%
Arizona	90%	10%	71%	29%
California	84%	16%	66%	34%
Colorado	81%	19%	63%	37%
Hawaii	71%	29%	51%	49%
Idaho	85%	15%	65%	35%
Montana	87%	13%*	70%	30%
Nevada	83%	17%	61%	39%
New Mexico	89%	11%	73%	27%
Oregon	82%	18%	68%	32%
Utah	82%	18%	56%	44%
Washington	82%	18%	59%	41%
Wyoming	81%	19%*	47%	53%

Table 2: The income status of children under age 18 living in the West of the United States, compared between parents having less than a high school education and parents who completed high school.[22]

Parental education and parental occupational prestige tend to be lower compared to peers who live above the poverty line.[10] This can be seen in the comparison between parental education

levels and child income levels seen in table 2. The educational deficit experienced by children living in poverty has been defined as the "income-achievement gap." Low-income children often begin school already behind in reading and math, and the gap only grows as they continue their education. Lower income children also experience accelerated school dropout rates in comparison to their advantaged peers.[11] Looking into adulthood, the persistence of an intergenerational low SES could be partially attributed to the development of mental health and substance abuse disorders during adolescence. These mental health issues could contribute to the increased dropout rate seen in lower-income children, as a low SES is associated with alcohol and substance abuse disorders and mental health problems such as depression and anxiety.[23]

Nutritional impacts have been seen in maternal nutrition, but we will now look at how nutrition quality impacts children. Vitamin B12, folate, retinoic acid, omega-3 fatty acids, zinc, and iron all play a role in regulating the gene expression that guides brain development. These nutrients also have been found to modulate neuroplasticity, dendritic arborization, synaptogenesis, and myelination. Because of the vast and crucial roles played by these nutrients, nutritional deficiencies have great implications on brain development and educational and intellectual achievement. As mentioned above, iron deficiencies lead to susceptibility to lead poisoning. Lead poisoning can then impact neuronal plasticity and synaptic communication, altering different sections of the brain[15].

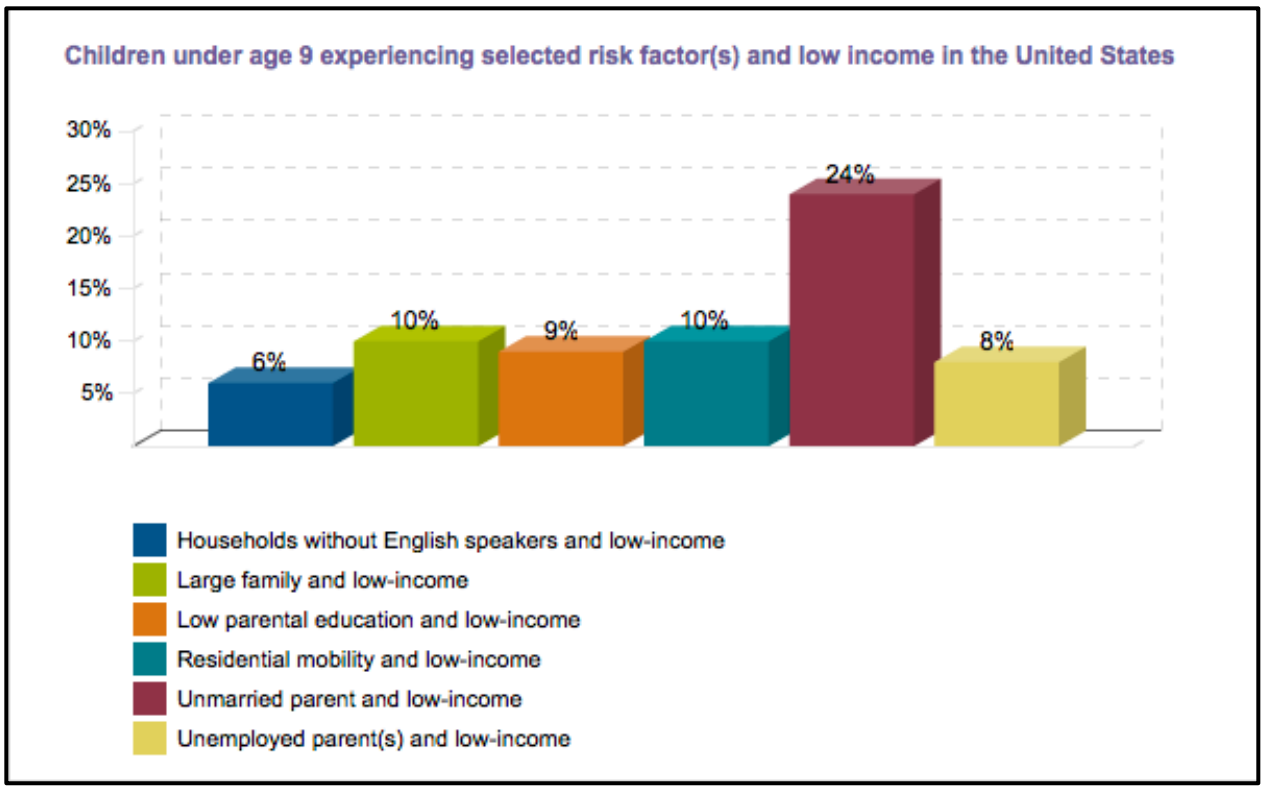

Figure 1: Percentage of children under nine years old experiencing a low familial income and various other risk factors, including living in households without English speakers, large families, low parental education, residential mobility, unmarried parents, and unemployed parents.[24]

The poverty cofactors mentioned above and seen in figure 1 have great implications on brain structure and function. The environment in which a child is raised will affect them. Maternal factors, such as stress and malnutrition, impact the developing fetus. Financial stress and insecurity lead to the development of chronic stress in a child. Environmental toxins, often found in low-income areas, have a myriad of detrimental effects on children. Parental conflict and lack of nurturance can increase stress in children and lead to decreased academic performance. A lack of stimulation and quality education during childhood will impact a child's cognitive and academic success. All these factors often accompany a low socioeconomic status. That is not to say that every poor child will be malnourished, or that every family living below the poverty line will experience parental conflict. However, more often than not, low-income families will

experience some of these poverty cofactors, which can impact the developing brains of the children in those families.

STRUCTURAL BRAIN CHANGES

There are several key regions of the brain that show the greatest changes in relation to childhood poverty. These areas include the frontal lobe, the temporal lobe, the prefrontal cortex (PFC), the amygdala, and the hippocampus. Changes in neurotransmitter and hormone levels have been noted, along with variations in the volumes of the brain's grey and white matter. This section will explore the observed brain changes along with some of the possible mechanisms and reasoning for the changes seen.

The frontal lobe is important for the top-down control of attention, inhibition, emotion regulation, and complex learning. The temporal lobe is associated with memory and language comprehension, such as identifying words, attaching meaning to words, and relating heard sounds with letters of the alphabet.[2] Small frontal and temporal lobes have been found in people raised in poverty. The size decreases of these brain regions explain as much as 15 to 20% of the achievement deficits found.[25]

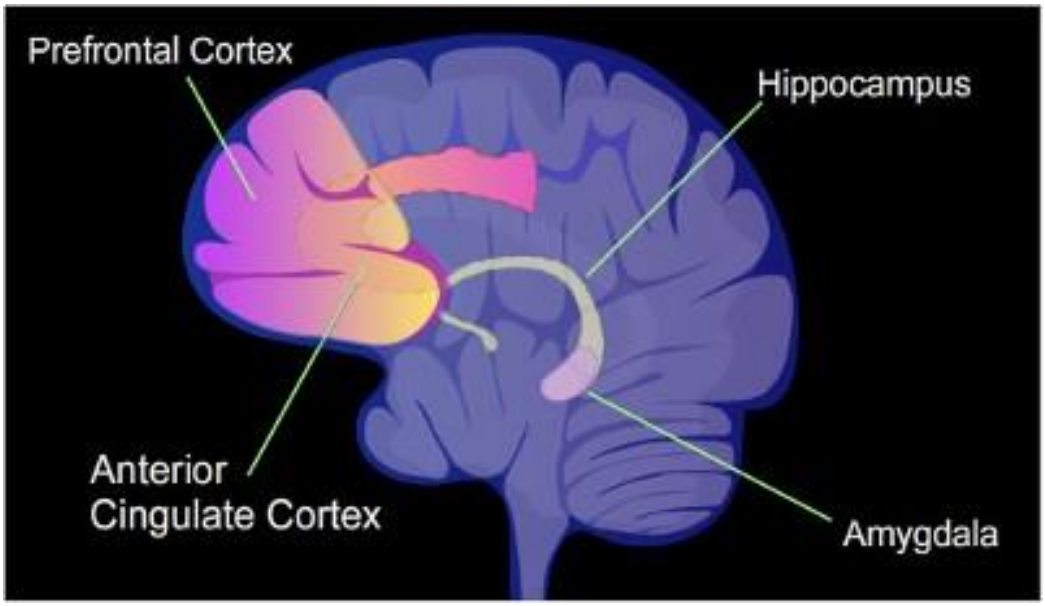

Figure 2: Model of the brain displaying the prefrontal cortex, anterior cingulate cortex, hippocampus, and amygdala.[26]

The prefrontal cortex, shown in figure 2, is responsible in part for higher-order planning, reasoning, and decision-making.[18] The PFC is also associated with emotional regulation, which will be discussed further on. Early childhood poverty reduced left dorsolateral PFC recruitment in emotional regulation.[27] Furthermore, a low SES at preschool age is predictive of reduced connectivity at school age between the PFC and other areas of the brain, such as the cortex, lingual gyrus, and posterior cingulate. This connectivity is especially important in the development of mental illnesses such as anxiety and depression.[6] It has also been shown that the PFC becomes more variable in its responses in emotional processing. The activity of the PFC is both increased and decreased in individuals facing situations involving interpersonal violence, maltreatment, caregiver deprivation, and poverty. It is more difficult to predict the response of the PFC in emotional processing in low-SES individuals. Additionally, it is thought that the PFC may serve a compensatory role in emotion regulation, similar to the amygdala.[28]

The amygdala is associated with emotional learning, motivation, and emotion and threat processing. The effects of childhood on the amygdala are not well-understood—some studies have noted that low childhood SES and risky family environments are associated with either greater or less-regulated amygdala activation. In some subjects, the amygdala was less controlled, but in others, greater control was exerted on the amygdala. A decisive result was not found.[18] In another study researching the effects of low childhood SES and childhood maltreatment, it was found that neither factor was related to amygdala volume.[10] Yet another study found that smaller amygdala volumes were found for children exposed to multiple forms of early life stress, including a low familial SES.[29] The size of the amygdala volume seems to be dependent on the age of the participant and the time of childhood the participant entered poverty.

Children who experienced early maternal deprivation have been shown to exhibit early maturation of amygdala-prefrontal connectivity. Children develop an adult-like neural phenotype in regard to their amygdala and PFC, which is believed to be a compensatory mechanism to deal with stress. Increased cortisol levels spur the development of the adult-like amygdala, which may provide a degree of emotional regulation. Initially, maternally deprived youths are less anxious than their counterparts who have not undergone maternal deprivation.[30] However, increased amygdala response has been noted to particularly occur when a child is faced with negative stimuli. When a low-SES child sees a picture of a negative face or situation, their amygdala is activated more than those of mid or high-SES children. There was not a difference noted when children were exposed to positive stimuli. Furthermore, the increased amygdala-prefrontal connectivity did not moderate any degree of internalizing, which will be discussed further on.[28] The increased amygdala activity may help children to process dangerous or adverse situations

faster, but adolescents who were raised in poverty and exhibit an adult-like amygdala tend to display increased anxious behaviors . Excluding SES, anxious phenotypes are associated with amygdala activity. The amygdala may also moderate oculomotor behavior. Children with amygdala hyperactivity were more likely to direct their gaze away from the arousing aspects of emotional stimuli and were more likely to avoid direct eye-contact than were their peers. Low-SES children were less able to ignore emotional distracter stimuli and distinguish between relevant and emotional information. This inability to distinguish has been attributed to increased amygdala engagement, as has the hypervigilance noted in low-SES children.[31] Studies have noted varied results regarding the activity and size of the amygdala in low-SES children, and further research must be performed to determine how the amygdala changes in regard to childhood poverty.

The hippocampus has been found to be significantly impacted by childhood poverty. The hippocampus is involved in learning and memory,[18] as well as the processing of spatial and contextual information.[2] The hippocampus is particularly sensitive to stress and stress experiences and plays a role in regulating the stress response.[10] The inverse relationship between childhood poverty and hippocampal volume is persistent, showing decreased hippocampal volume with greater childhood poverty.[18] Because of the hippocampus' role in responding to stress, decreased hippocampal size is attributed to the increased amount of stress experienced by children raised in poverty.[10] It is thought that increased exposure to stress will lead to preferential recruitment of the insula, which is associated with emotion generation, instead of recruitment of the hippocampus, which is associated with emotional regulation. This leads to a decrease in hippocampal activation and a decreased hippocampal volume. This effect is observed in adults

who were raised in poverty.[27] Smaller hippocampal volumes were also found in children who were physically abused and the smaller volumes were associated with behavioral problems[29] and poor memory performance.[32] Children raised within a family with a high-SES tend to have larger hippocampi.[18] Increased hippocampal volumes were found to partially mediate the relationship between early life stress, such as poverty, and behavioral problems.[29]

Variations in neurotransmitter and hormone levels have been associated with a low SES. Childhood poverty is correlated with elevated levels of chronic stress, noted by increased blood pressure and basal cortisol and catecholamine levels. These effects contribute to the higher allostatic load observed in chronic stress.[27] Basal cortisol and catecholamines such as epinephrine are stress hormones. Excessive stress hormones can have effects that undermine cognition and mental health.[18] Elevated cortisol levels particularly alter the function of brain regions with abundant glucocorticoid receptors, making them vulnerable to stress hormone exposure. The prefrontal cortex and hippocampus both have many glucocorticoid receptors and are both effected by childhood poverty.[33] Changes in these vulnerable brain structures influence the regulation of the hypothalamic-pituitary-adrenocortical (HPA) axis as well as executive function abilities. The HPA axis is also known as the stress axis and is responsible for the stress response and the regulation of cortisol in the body.[20] Dopamine levels have also been shown to undergo variation in individuals living in poverty. This is especially concerning due to the relationship between high dopamine levels and schizophrenia. Childhood stress was associated with increased stress-related dopamine activity in the prefrontal cortex. Increased dopamine levels could be compensatory in children and serve to promote resilience by regulating prefrontal

dopaminergic neurotransmission with predicted stressful environments. However, increased dopamine activity may enhance the risk of developing psychosis.[34]

Low SES is associated with atypical grey and white matter development.[2] This primarily refers to brain volume, and children living under the poverty line are observed to have overall smaller brain volumes.[25] Grey matter appears to be particularly sensitive to early environmental influences.[35] Children living below 1.5 times the federal poverty line were found to be three to four percentage points below the developmental norms for their sex and age. Children living below the federal poverty line were found to have a gap of eight to ten percentage points below their peers.[2] These smaller brain volumes, especially smaller frontal lobe, temporal lobe, and hippocampal volumes, are associated with decreased cognitive and academic performance.[25] As previously mentioned, hippocampal and prefrontal cortex changes have been noted in low-SES children. Lower grey matter volume in both of these structures may mediate the relationship between childhood adversity and adult anxiety. The possible augmentation of the hippocampus and PFC in relation to adversity could contribute to the development of anxiety and fear in adolescence, and may increase the proclivity of youth raised in poverty developing anxiety disorders and PTSD.[28] Child internalizing symptoms, which will be discussed later on, were associated with lower grey matter volumes in the superior frontal gyrus, anterior cingulate cortex (figure 2), and the precuneus. Increased internalizing symptoms may be correlated with the development of depression.[36]

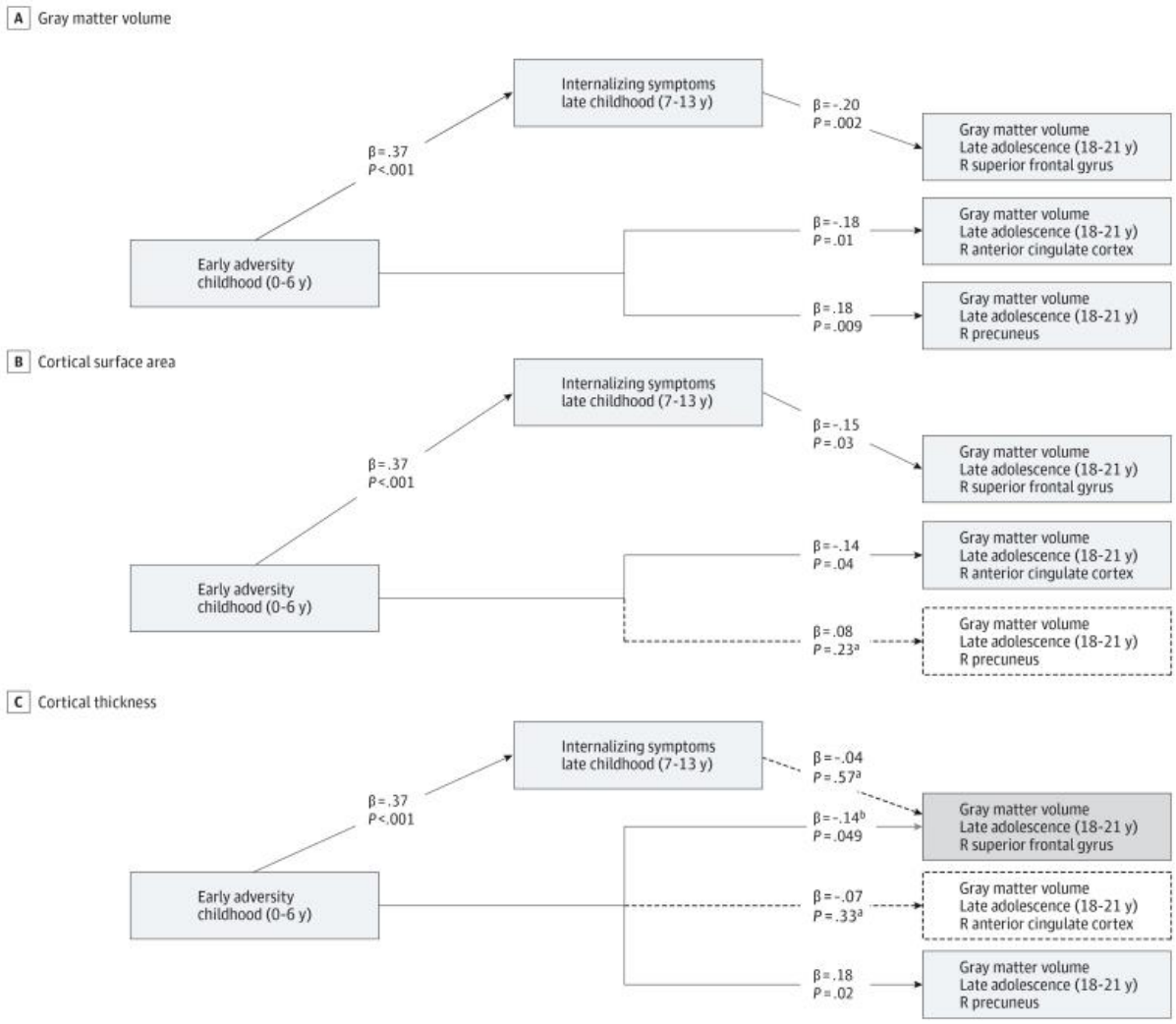

Figure 3: Early childhood adversity and how it relates to grey matter volume, cortical surface area, cortical thickness, internalizing symptoms, and variations in different parts of the brain.[36]

Figure 3 lays out the structural brain changes observed in early childhood adversity in relation to grey matter volume. Low childhood SES is also related to reduced grey matter volume in the cerebellum. The cerebellum plays a significant role in motor skill and function. During childhood adversity, the cerebellum shows increased activation, which may contribute to the hypervigilance observed in low-SES children. However, this increased activation eventually yields to decreased grey matter development in the cerebellum, showing that cerebellar activity may be adaptive in the short-term, especially in regard to fight-or-flight scenarios, but may be

maladaptive long-term. Decreased grey matter volume in the cerebellum increases the risk of developing mental illness.[37] Also, low grey matter volume is associated with decreased maternal sensitivity. Girls who experience early childhood adversity and low-SES may show lower levels of maternal nurturance due to their decreased grey matter volume. This contributes to one of the poverty cofactors observed above regarding parental involvement and nurturance.[35]

The brain changes observed in children raised in poverty include changes in the frontal lobe, the temporal lobe, the prefrontal lobe, the amygdala, and the hippocampus. Additionally, changes in neurotransmitter and hormone levels and grey and white brain matter are noted. These changes are general trends seen in children raised in families with a low SES. They are not universal to every child raised in poverty. Mechanisms accounting for these changes have been hypothesized and researched, but there continues to be much to learn about the brain changes associated with childhood poverty.

IMPLICATIONS OF STRUCTURAL BRAIN CHANGES

Structural changes in a child's brain are not without consequences. The variations outlined above influence a child's future. As of now, the specific mechanisms relating brain changes to long-term impacts and behavioral changes have not yet been determined. For example, we know that the PFC is responsible for attentional deployment, so alterations to the PFC can affect attention, but it is not known how or to what degree. Research is being done attempting to determine whether there is a causation to the correlation, and if so, the mechanism behind the changes. This section will overview the long-term effects of childhood poverty regarding memory,

achievement, processing, and behavioral and social interaction.

Working memory and language are the most sensitive neurocognitive systems in regard to childhood poverty. Working memory is defined as the temporary storage mechanism that allows humans to retain a limited amount of information for a short period of time. Childhood deprivation is predictive of working memory capacity in adulthood. One reason for a lower working memory capacity in adults who were raised in poverty deals with self-regulation. Self-regulation is the ability to maintain the emotional and behavioral self-control necessary for goal achievement in the face of competing demands. These competing demands could be social or physical. A loose example of this would be remaining focused on studying for an exam while surrounded by friends. The ability to direct focus and attention is managed by the prefrontal cortex and reward and appetite processing are managed by deeper brain structures such as the ventral striatum. It has been observed that there is a significant statistical interaction between children raised in poverty and decreased prefrontal cortex recruitment. Decreased PFC recruitment could be responsible for the decreased ability to self-regulate noticed in children raised in poverty. Inferior self-regulatory skills are observed in childhood and continue into adulthood, presenting with decreased ability to direct attention away from social and physical demands and increased vulnerability to stimulating environmental demands. Relating this back to working memory, it has been seen that children with better self-regulatory skills are able to develop more flexible and efficient coping strategies to deal with competing social and physical demands. In turn, these strategies help to offset the decrease in working memory capacity observed in children living in poverty.[11]

Memory capacity is also related to verbal capacity. Children with higher vocabulary skills are able to produce more complete and accurate memories, due to the correlation between verbal labels and increased accuracy of memory recall. In one experiment, two groups of children were shown a scenario and then asked to recall what happened in the scenario. One group of children was provided with verbal labels to define what was happening in the scenario, while the other group was not provided with these verbal labels. The group of children who were provided with verbal labels spontaneously produced more and more accurate information. Following from this result, researchers looked at children with lower language skills and their ability to recall accurate memories and found that decreased language skills and decreased accurate memory recall accompany one another. As mentioned previously, lower SES children have a low level of language complexity and decreased language skills. This leads to a decrease in working memory capacity and accurate memory recall.[38]

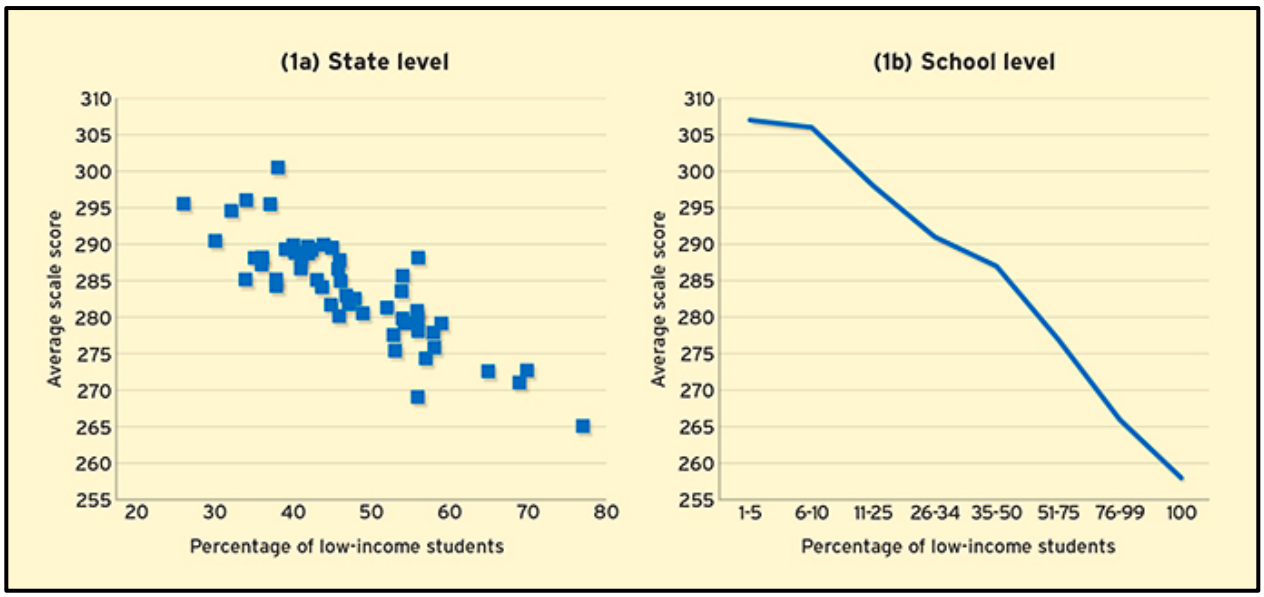

Figure 4: The relationship between the percentage of low-income 8th grade students and the average scale score performance on the math section of the National Assessment of Educational Progress (NAEP) observed at both a state level and a school level.[39]

Children raised in low-SES households tend to have decreased educational and intellectual attainment when compared to their more advantaged peers, as seen in figure 4. According to one study, children from low-income households scored four to seven points lower on standardized tests when compared to scores from children from moderate or high-income households. The same study attributed up to twenty percent of the achievement gaps in test scores to maturational lags in the frontal and temporal lobes. It was also observed that the longer children live in poverty, the greater their academic deficits.[2] By age three, a child's academic performance and level of cognitive function can be predicted by the income-to-needs ratio of the child's family. The academic achievement gap is evident by kindergarten and grows as the child grows. The achievement gap is most evident in middle adolescence. This gap has been growing longitudinally over the past four decades and is now greater than the black-to-white student achievement gap.[40] In a study performed in 1991, it was found that poor students ranked in the 19th percentile on assessments while students from middle to upper income families ranked in the 66th percentile on assessments. In 2004, children from low-income families scored at about the 30th percentile, while students from high income families scored at the 70th percentile. In 2006, 43.5% of low-income students did not meet any of the required subject area assessments and 13.2% of low-income students met all of the required subject area assessments. Through these studies, it was observed that students from low-SES families consistently score well below average in school assessments, regardless of ethnicity or race. Differences in academic achievements are noticed between students in various levels of poverty. Children from very poor households (with income below 50% of the poverty line) scored 7 to 12 points lower on standardized tests, while children in poor households (income between 50 and 100% of the poverty line) scored 4 to 7 points lower than children from near-poor households.[41]

Possible reasons for the academic deficit observed between students from low-SES households and students from households with a mid to high-SES are family stability, teacher expectancy, and student housing instability. As mentioned previously, low-SES households tend to have a high degree of instability and chaos. Familial conflict and lack parental nurturance negatively affect academic achievement. Additionally, children from low-income households tend to have less exposure to vocabulary than children from upper class families. Teachers of low-income students have been found to have lower expectations for them than they do for their high-income students. Students commonly rise to the expectations placed upon them by teachers. Due to labeling theory, if teachers have low expectations for their students, their students will meet those low expectations and exceed no further. We have previously discussed housing instability and the number of moves experienced by low-income children. In a study performed in 2003, it was found that one student move equated 32 days absent from school. Additional moves have increasingly negative effects on academic performance, as the moves disrupt patterns and relationships both socially and academically.[42]

Similar to the self-regulation mentioned earlier, children raised in low-SES households have a diminished ability to emotionally regulate and process in adulthood. Emotional regulation is used when an emotionally upsetting stimulus is reappraised in order to dampen negative responses to the stimulus. Emotional regulation can be thought of as appraising the situation (slowing down and thinking about it) and shifting attention to specific tasks (focusing on what can practically be done). An example of emotional regulation would be dealing with an insulting comment. A colleague makes a negative comment regarding your work ethic and you have to choose how to

respond. The choice made regarding how you will respond is emotional regulation. If put into the example situation, those with high emotional regulation could think rationally through the comment made and choose how to respond appropriately. A diminished degree of emotional regulation would result in inappropriate analysis of the negative comment made and the inability to dampen emotional responses in order to think rationally about the way to respond to the colleague. Emotional regulation is primarily subconscious and is something that humans do almost instantly when faced with an emotionally-stimulating situation. Interestingly, the effects of childhood poverty on emotional regulation are more pronounced when in a stressful situation. The greater the stress, the greater decreased ability to properly emotionally regulate.[27] This leads to a diminished inability to respond to stress and emotional stimulus in a way that is appropriate to the situation. Self-regulation can be subdivided into externalizing and internalizing behaviors. Externalizing behavior is chiefly behavioral and deals with how a child responds to a stimulus. Internalizing behavior deals with how a child processes emotion and situations within themselves. High levels of childhood self-regulation have been linked to academic readiness and success, while low levels have been linked to poor physical health, substance abuse, high rates of criminal offenses, and psychiatric disorders. In one study, it was observed that low-SES and high-SES children start out with similar self-regulatory capacity. However, as children entered elementary school, greater self-regulatory problems were observed in children from low-SES households.

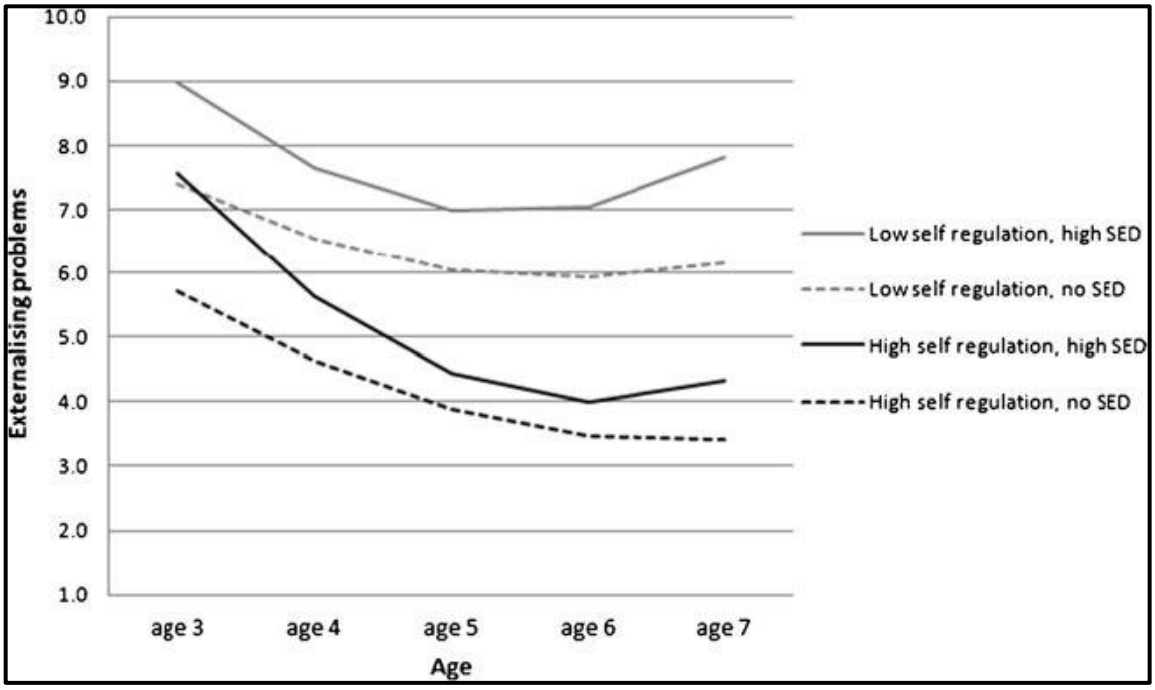

Figure 5: The relationship between age and externalizing problems in childhood, studied between no and high socio-economic disadvantage (SED), or high or low-SES, respectively[43]

As figure 5 shows, the gap among children in poverty compared to children living above poverty in regard to self-regulation increased over time. This was measured by observing externalizing and internalizing behaviors in children age 3-7. Externalizing behaviors were rated by degree of hyperactivity and conduct problems observed, and internalizing problems were judged by observing emotional symptoms and using peer problems sub-scales, such as degree of solitary play, having one or more good friends, being bullied, and getting along better with adults than with children. Variables that are partially responsible for the low level of self-regulation observed in children raised in poverty are household chaos and poor parenting, including low levels of parental involvement, less support, and inconsistent discipline. These variables are often observed in poor families. One factor that mitigated the association between low-SES and low self-regulation was the level of language ability observed in some children. Increased verbal ability provides children with a way to use expressive language to communicate their needs and

feelings and enhances their ability to understand the thought and feelings of others. Verbal ability is also related to intelligence and the ability to assess and handle problems of adversity.[43]

Decreased working memory, intellectual and educational achievement, and emotional regulatory ability are the most prominent long-term effects observed in individuals raised in poverty. However, other effects of poverty have been noticed and will be briefly discussed. Childhood poverty has been associated with higher levels of annoyance with the cry sound of the individual's child. In short, if someone was raised in poverty and then has a baby, they will be more annoyed with their child's cry than a parent who was not raised in poverty would be. Both genders experience the same amount of neural activation associated with higher levels of annoyance, leading to a reduced desire to approach the crying infant. This could partially account for the decreased level of physical parental nurturance, such as hugging and cuddling, seen in parent-child relationships in low-SES households.[33]

The final long-term effect of childhood poverty that will be discussed is decreased mental health. It is predominately thought that children raised in low-SES environments are not necessarily more likely to develop a mental illness, but if the child was already at risk for mental health problems, poverty can exacerbate mental illness. In children without mental health difficulties, childhood poverty does not have a significant impact on mental health. However, because children are often living in poverty from birth, it is difficult to determine the influence of poverty on mental health and the development of mental illness.[44] Returning to the idea of self-regulation, children of low-SES families are more likely to develop internalizing problems than their more advantaged contemporaries. Inappropriate internalizing behaviors lead to anxiety,

depressive symptoms, and withdrawal. Additionally, children's chronic exposure to poverty-related adversity is predictive of higher internalizing behavioral symptoms of sadness, depression, and worry. Children from low-SES families experience a higher risk of rejection from peers, feelings of failure in social situations, social isolation, loneliness, and an overall lack of success in navigating the social and academic demands faced in their schools and neighborhoods, primarily due to their inappropriate methods of self-regulation. These factors are predictive of future mental illness.[45]

One study researched the relationship between low-SES school-age children and their severity of negative mood/depression. It was found that a low-SES was predictive of a high negative mood and greater depression severity. A possible explanation for this was predicted to be the level of connectivity between the left hippocampus and the right superior frontal cortex and between the right amygdala and the right lingual gyrus. A low degree of connectivity correlated with a greater negative mood and depression severity in the school-age child, and poor children have lower degrees of connectivity between the aforementioned structures than do their higher-SES peers.[6] The relationship between childhood poverty and mental health is not fully understood and more research is needed to determine the true effect childhood poverty has on mental health.

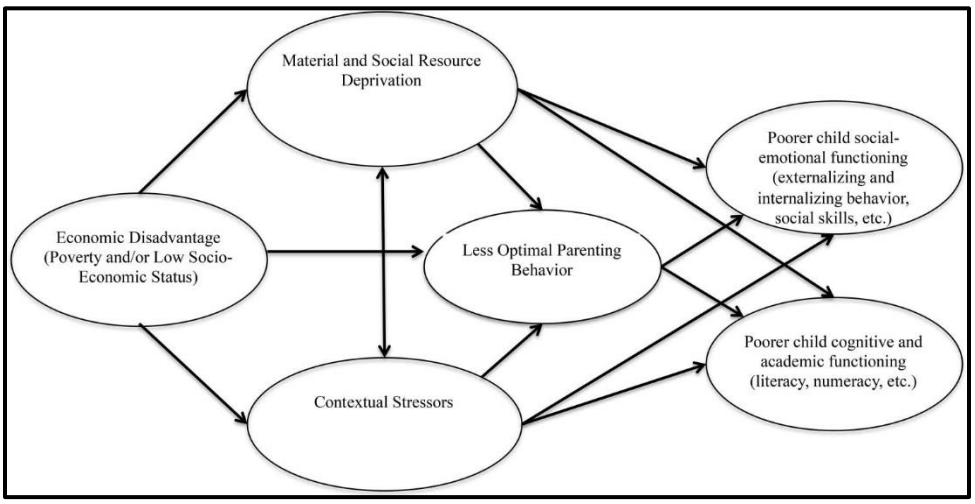

Figure 6: The relationship between economic disadvantage and the subsequent effects, resulting in poorer child social-emotional, cognitive, and academic functioning.[40]

Childhood poverty has far-reaching effects, such as alterations in long-term memory, educational achievement, emotional regulation, parental nurturance, and mental health. Though these effects outlined above and in figure 6 are not well-understood and the potential correlation between brain changes and behavioral impacts are not known, it can be seen that childhood poverty does have long-term effects on a child's future.

PREVENTION AND REMEDIAL STRATEGIES

In light of the many negative impacts childhood poverty has on the brain and on a child's future, it can be tempting to become discouraged and overwhelmed. However, much research is being done on ways to circumvent and prevent the effects of childhood poverty. While it is important to research prevention for all types of poverty, due to the effects on the brain mentioned above as well as the proportion of children living in poverty compared to other age demographics, childhood poverty is being targeted specifically for research.

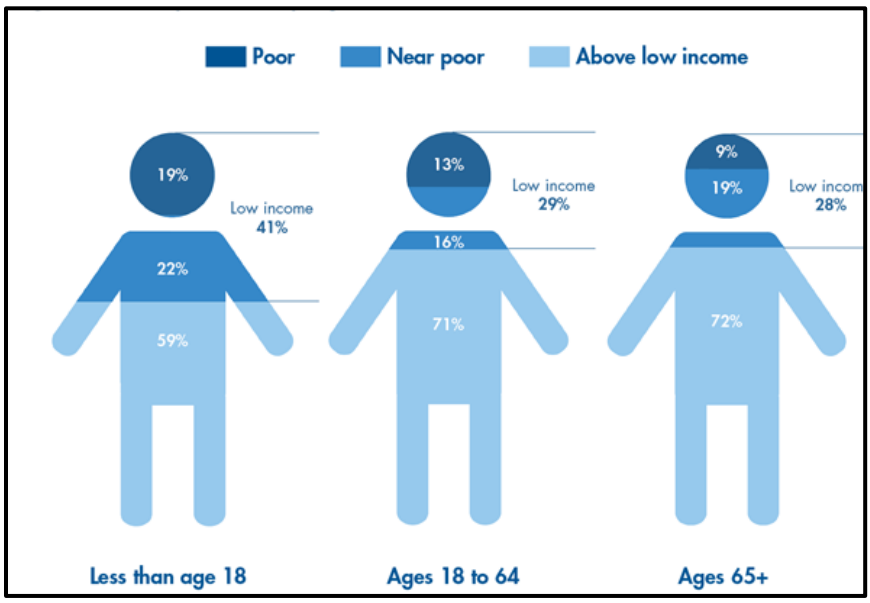

Figure 7: Representation of the family income by age percentages taken in 2016[3]

In figure 7, it is observed that there is a greater percentage of people under the age of 18 who are poor or near poor than there are in other age demographics. As outlined above, poverty has many effects on the developing brain. If poverty is such a detriment to children and their achievement and development, what will happen when this current generation enters the workforce? Economically speaking, the cost of child poverty and the estimation of future lost productivity and increased social expenditure amounted to a total cost of approximately $500 billion each year. This cost amounts to nearly 4% of the gross domestic product in the United States and can be attributed to decreased productivity and increased costs of crime and health care. Additionally, if the cycle of intergenerational poverty continues, this current generation of children in poverty will grow up and have children of their own, who will most likely live in poverty. Those living in poverty experience a low degree of social poverty, meaning that parental income and economic advantage will significantly influence their children's income and economic advantage. Because of this, there is an observed decline in the possibility of economic improvement for the poor. Rich children become rich adults and poor children become poor

adults.[46] Poverty is a vicious cycle that will continue unless active steps are taken to prevent the progression. Returning to the effects childhood poverty and its cofactors have on the developing brain, what can we do to prevent or remedy these changes? As previously mentioned, research is being done to discover how we can prevent the functional and physiological changes occurring in childhood poverty. What has been found to be most effective at this point in time is parental involvement and mental and verbal stimulation. We will also briefly discuss the possibility of a "plasticity allele" and how that could influence brain changes.

The current most promising remedy to the effects of childhood poverty is parental involvement, particularly maternal involvement. Involvement could mean positive or negative involvement, such as reading to a child or child abuse, respectively. In this context, involvement will strictly refer to positive involvement. The type and level of circumvention of the effects of childhood poverty on the brain provided by maternal nurturance and involvement does depend on the quality and level of care given to the child. However, studies have shown that simply the physical presence of the mother is a buffer on the HPA axis, or the stress axis, which is outlined above. Low-quality early care is still effective in overriding the HPA response and the potential learned aversions to the primary caregiver.[20] Even low-level and low-quality maternal care can assist in preventing the effects childhood poverty has on the developing child. Nevertheless, as would be expected, higher levels of maternal care result in fewer negative effects of childhood poverty. In a study of rat pups and maternal nurturance, the pups that were exposed to high levels of maternal care demonstrated more glucocorticoid receptor expression in the hippocampus. The pups also showed better regulated stress responses and better cognitive performance than did their counterparts who received less maternal involvement and care. One notable observation in

this study is that the improvements seen in the pups given a high level of maternal care were not reliant on whether the pups were biologically related to the dam. This could have impacts on how adoption and foster care are viewed in relation to buffering the effects of childhood poverty. In human studies, is has been observed that less supportive and more hostile parenting (an example of negative involvement) in preschool may be partially responsible for the lower family income-to-needs ratio and smaller hippocampal volume in the child three to six years later. The same study attributed this relationship to maternal care regulating gene expression in the brain. If there is a low level of maternal involvement, gene expression is effected, and children show smaller hippocampal volumes and a lack of HPA-axis buffering.[18] A similar study noted that the poor hippocampal development observed in children raised in poverty is partially mediated by the maternal nurturance experienced in preschool. These studies provide evidence demonstrating that increased quality and levels of parental nurturance, especially maternal nurturance, during childhood is a promising intervention target for the prevention of poverty's effects on the brain. It is possible that enhanced parental involvement could mitigate the poor cognitive and academic achievement levels experienced by children living in poverty.[25]

A second potential target for the prevention of the deleterious effects poverty has on the developing brain is the level of mental and verbal stimulation experienced by children in poverty. Children show an exponential growth in language development between 14 and 46 months of age. They learn new words, new verb tenses, and new uses for familiar words. At 26 months, the language complexity observed in high-SES children is double that of low-SES children.[47] It is likely that children from higher-income families are buffered from the behavioral deficits attributed to lower white matter volumes observed in low-income children. This

buffering comes from the increased level of mental and verbal stimulation typically received by higher-income children.[13] For every increase of $5,000 in annual familial income, a child's vocabulary scores are raised nearly two points. A possible explanation for this is the higher degree of leisure time noticed in higher-income families. The amount of leisure time parents spend reading correlates to a child's cognitive and language development. Though there could exist a high degree of language complexity in low-SES families, there is a trend of low-SES families having low levels of educational achievement. Less educated parents are likely to use fewer words, less complicated syntax, and fewer verb tenses not in the present tense. Low-SES parents are more likely to choose a low number of words in communicating with their child than higher income parents are. For example, a parent could tell their child, "Get the plate," or tell them, "Could you please pick up your red plate and put it in the left side of the sink?" Both sentences will most likely result in similar outcomes, but the number of optional words used differs greatly.[47] As mentioned above, increased verbal ability correlated with a higher degree of self-regulation, leading to increased understanding of the self's and others' feelings and thoughts as well as increased academic readiness and success. Children with a higher verbal ability may also be better able to assess and handle stressful situations and problems of adversity.[43] The achievement gap of vocabulary use between high and low-SES children at 26 months of age remains steady for at least the next four years of life. This indicates that once a low-income child starts kindergarten, they are already behind their higher-income peers in cognitive achievement and verbal ability, as well as their level of self-regulation. Higher-SES homes tend to have rich home learning environments (HLE), while low-SES homes have poor HLE's. Contributors to a rich HLE are availability of books and parents reading to their children.[47]

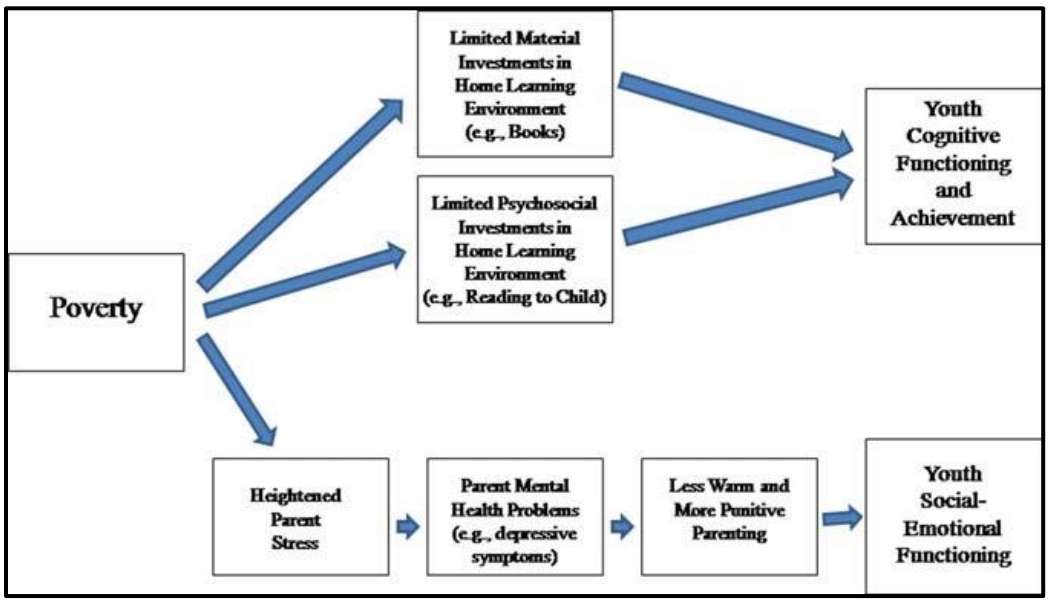

Figure 8: The relationship between poverty and other factors, such as home learning environments, in cognitive and social-emotional functioning and achievement.[48]

Figure 8 shows the link between poverty and decreased cognitive functioning as being due to limited materials and investments in the HLE, such as books and reading to children. If more low-income parents had increased access to books and learned the importance of reading to their children, the vocabulary learned by the children and their language ability could increase.[48]

A common argument used to explain why people remain in poverty is a lack of work ethic. It is believed that poor people stay poor because they do not work hard enough. This attitude is typical in our American Dream-influenced society, where we praise the "rags to riches" type of stories. We can point to individuals who have "made it out" by working hard to escape poverty. We can look at two individuals raised in similar circumstances and see that one has stayed in poverty and the other is living in the upper-middle class. Why do some people stay in poverty and others rise in society? A potential explanation is the existence of a "plasticity allele". Plasticity refers to changes in the brain induced by environmental stimuli. The effect of plasticity

is observed when someone has a stroke, resulting in decreased language ability, and is able to regain full language function as a result of therapy. The brain can "re-wire" itself in order to compensate for deficits. It has been postulated that genes explain a vast amount of the variance between intellectual and academic achievements and brain structure in high-SES children and what is observed in low-SES children. Gene variation can determine amounts of vulnerability or resilience observed in children in specific environment. There are points of time in brain development, deemed "sensitive periods," when plasticity is greatest. These sensitive periods depend on the function and complexity of the brain region involved and the experiences of the child, not simply the age of the child. The genes involved in plasticity have been termed "plasticity alleles," and could be responsible for the variations in the amount of resilience and achievement observed among children raised in similar environments.[18]

CURRENT STRATEGIES

In light of these potential methods of circumventing the effects of poverty on the developing brain, several programs have been developed to assist low-income families provide their children with nurturance and mental and verbal stimulation. It is important to make these resources widely available at little to no cost to low-SES families. One such resource is Reach Out and Read (ROR), which is a program focused on providing book reading during well-child visits. This program emphasized to parents the importance of reading to their children and provides books for them to use, at the cost of $25 per child per year. A second program is the Video Interaction Project (VIP), which is designed to complement ROR in pediatric primary care. VIP begins at birth and provides families access to a child development specialist during well-child

visits. During the sessions with the specialists, parent-child interactions are videotaped and then reviewed to promote parental self-reflection. Books and toys are provided during the videotaped sessions and, upon review, the specialist enforces positive parenting behaviors and initiates a guided discussion regarding the use of these books and toys in parenting and child-interaction. ROR and VIP are the most common resources utilized by pediatricians as they are low-cost and widely available.[49]

Programs that are less cost-efficient but potentially more helpful include Bright Beginnings, the Incredible Years program, the Thirty Million Words Project, and Project ASPIRE. In the Bright Beginnings program, low-SES families are identified and referred from primary care clinics to meet with a trained community volunteer in various settings. Depending on the patient's situation, the family will meet with the volunteer at a clinic, a community center, or during a home visit. The Bright Beginnings program is less time-intensive, as the volunteers meet with the families only once during the second and third years of the child's life. During the session, parents receive a picture book and written materials about activities that can promote their child's language and social development. The written materials are accompanied by a demonstration of the activities that can be done with the child. This demonstration is helpful in cases of parental or familial illiteracy or if the family predominately speaks a language other than English. The Incredible Years program specifically targets families of young children with behavioral problems. The program lasts 10 weeks and parents are provided with 2 hours of training per week for the duration of the program.[25] These programs, used in conjunction with ROR and VIP, can enhance cognitive and socioemotional development among low-SES children. The use of programs focusing on the development of positive parenting through reading

aloud to and playing with children show great potential in the prevention of the negative effects poverty has on the developing brain. These programs are predominately low-cost and have a wide reach among low-SES populations.[50]

One caveat to the use of these programs mentioned above is the necessity of access to healthcare providers. All these programs come about by physician or healthcare professional referral. If a family does not have access to a pediatric clinic or is non-compliant with well-child visit recommendations, it is difficult to get involved in these programs. The Thirty Million Words project (TMW) and Project ASPIRE get involved in the lives of children somewhat independent of pediatric clinics. TMW is associated with clinics, but is also involved in early education centers, preschools, community centers, and community-based programs.[51] TMW trains parents in providing verbal and mental stimulation for their children. The importance of reading and talking to children is emphasized. Project ASPIRE (Achieving Success by Promoting Readiness for Education and Employment) exists in Arizona, Colorado, Montana, North Dakota, South Dakota, and Utah. The purpose of this program is to provide supplemental income to low-SES families, train families, provide paid employment for low-SES youth in high school, offer financial education and self-determination training for the youth and their family, and provide case management services to the youth and their family.[52] ASPIRE is offered to elementary school and high school-aged youth and focuses on providing resources for their future success. Both TMW and ASPIRE provide opportunities for parents to become active participants in their children's education and learning environments by providing the parents with proper tools, positive reinforcement, and an understanding of their own importance in their child's growth and development.[53]

CONCLUSION

Poverty is an intricate and complex subject and social issue. Poverty in childhood adds even more complexity. Many different factors, ranging from housing insecurity to nutritional deficiencies, can account for the structural brain changes observed in the developing brain of a child raised in poverty. It can be difficult to account for if and how structural changes in the brain affect a child's life, but behavioral changes are observed in children raised in poverty. The links between the brain changes and behavioral changes are unclear. These brain changes likely have a myriad of effects on a child's life and future, including level of academic achievement and ability to self-regulate. Thankfully, potential targets have been identified to alleviate the effects of poverty on low-SES children. Many organizations have already begun utilizing these targets through providing books and resources to low-income parents and children. However, with the statistics of nearly one out of every five American children living in poverty, the efforts being made to reduce poverty are not enough. More research must be done to discover exactly how poverty affects children. We have some idea of the different components of poverty and how they influence the brain. We are also aware of some of the implications of these brain changes. That being said, we observe much more correlation than causation, and in order to provide greater relief to poor children and families, more information about the causes of poverty must be discovered. We must concurrently develop new strategies for employing the observed poverty targets in poverty relief. How can the negative cofactors in poverty be reduced? What other methods can be adopted for improving levels of parental nurturance and verbal and mental stimulation in low-income families? With so many children living in poverty and soon entering

the workforce, it is crucial to find ways to circumvent the deleterious effects of poverty and prevent the cycle of poverty from continuing to the next generation. This is an exciting time of development and discovery. If we can form novel ways to decrease childhood poverty rates and reduce the brain changes observed in childhood poverty, we can influence this generation and many generations to come.

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