THE STAMP OF POVERTY

Growing up in a poor family can leave a mark on the developing brain. Understanding how and why has important implications for educators and society

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ONLY

Imagine that you are a child again. In this version of your childhood, you arrive at school hungry, tired and anxious. Your mother was not able to pay the rent this month. The cupboards are bare. A car alarm went off late last night, and it fell to you to soothe your baby brother back to sleep. You woke up early to take the bus across town, and by the time the school bell rings, you have so much on your mind that it is difficult to concentrate.

Myriad stressors collect and compound for children who grow up in poverty. Although their stories are all different, we know that the many challenges they face can have a lasting impact. In the U.S., one in four infants and toddlers lives below the federal poverty line.

Despite our societal desire to see education as an equalizer that elevates people from difficult circumstances, social scientists have known for some time that the truth is not so simple. The income of the family you are born into has a powerful effect on educational outcomes and, in turn, future job prospects and economic security. Education researcher Sean Reardon and his colleagues at Stanford University recently completed an analysis showing that children in school districts with high levels of poverty score an average of four grade levels below peers from the most affluent districts on tests of reading and math. And kids born to a low-income family have a far worse chance of getting a college degree than children born to a high-income family, in turn constricting economic and career opportunities.

As disquieting as these inequities may be, this so-called income-achievement gap is not new. Educators and social scientists have been tracking the relation between school success and poverty for roughly half a century. Although there is now some evidence that the divide may be starting to narrow—after three decades of expansion—the pace of change is too slow to help this generation or even the next. In fact, it could take 60 to 110 years to close the gap at its current rate of change, according to a 2016 calculation by Reardon.

In the meantime, strong evidence has begun to emerge about how family income relates to the development of a child's brain. In essence, scientists are finding anatomical differences tied to poverty—and some of this variation has implications for education. Everything that is learned, after all, depends on the brain's plasticity, its ability to grow and change. The new discoveries, in turn, serve not only as an added call to action but may also fuel ideas about how to best intervene.

FAST FACTS

THE BRAIN AND POVERTY

1. Several studies have now uncovered a link between socioeconomic status and brain development.
2. On average, children from lower-income families appear to have a thinner cortex in early childhood than their peers from more affluent homes.
3. Although the best strategy for mitigating the effects of early deprivation is prevention—in this case, tackling child poverty at a societal level—various research groups are implementing efforts to help kids in need.

Building the Brain

At birth, we have a rich supply of both gray matter, which is primarily composed of cell bodies, and white matter, which encompasses the tracts of cablelike axons that transmit signals from one neuron to the next. We start out with more neural material than we strictly need. The brain is sculpted into a more efficient organ as we learn and grow, strengthening some networks, eliminating others.

From late childhood through early adulthood, a part of the brain called the neocortical gray matter steadily thins. This area comprises six layers of cortex that cover the brain and support perception, language, thought and action. Researchers believe this thinning reflects a massive pruning of cells and the connections between them. Also during this life stage, white matter develops in ways that improve the connectivity of large-scale networks across the brain.

Scientists have only recently begun to examine how socioeconomic status (SES) might influence the normal course of brain development. SES is a complex construct that is measured by combining educational attainment, income and occupation. There is substantial variation among individuals and families at every socioeconomic level, making it hard to generalize about an individual's experiences. In addition, disadvantages, where they exist, tend to co-occur or correlate with one another, so it is difficult to relate specific circumstances to particular outcomes. For example, very low SES or poverty is associated with poor health, family instability and high stress. It can also entail malnutrition, limited health care, modest language and intellectual stimulation at home, inferior schools and lowered social expectations. These conditions could all, in turn, affect neural and cognitive development.

Children in high-poverty school districts score four grade levels below peers in the wealthiest districts, a recent analysis found.

A classic series of experiments conducted in the 1960s at the University of California, Berkeley, proved that adverse early environments harm the brain in rodents. Neuroscientist Marian Diamond showed that rearing rats in an impoverished environment—lacking toys and opportunities to socialize—hampered their brain development and ability to learn.

Such studies would be unethical in humans, but a long-term follow-up of Romanian children who had been warehoused in an appalling system of state orphanages found similar outcomes. Begin-

INEQUALITY, BY THE NUMBERS

When economists calculate income inequality for nations, the U.S. has both the greatest private wealth and the greatest income inequality in the developed world. People born into the poorest families face many challenges.

14.5 million children under age 18 live below the poverty line in the U.S.

$24,300 is the federal poverty line for a family of four

1 in 3 Americans living in poverty are under the age of 18

45 percent of people who spend at least half their childhood in poverty will still live in poverty at age 35

77 percent is the chance that a child born in the upper-income quartile will complete college by age 24

9 percent is the chance that a child born in the bottom-income quartile will complete college by age 24. A college degree is associated with a 98 percent increase in hourly pay

SOURCES: *CHILD POVERTY IN AMERICA 2015: NATIONAL ANALYSIS*. CHILDREN'S DEFENSE FUND, SEPTEMBER 13, 2016 (*children in poverty*); U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES (*poverty line*); *CHILD POVERTY AND INTERGENERATIONAL MOBILITY*, BY SARAH FASS ET AL. NATIONAL CENTER FOR CHILDREN IN POVERTY, DECEMBER 2009 (*poverty at age 35*); *INDICATORS OF HIGHER EDUCATION EQUITY IN THE UNITED STATES: 45 YEAR TREND REPORT*. REVISED. PELL INSTITUTE FOR THE STUDY OF OPPORTUNITY IN EDUCATION AND PENN ALLIANCE FOR HIGHER EDUCATION AND DEMOCRACY, 2015 (*college completion for bottom quartile*); "IS COLLEGE WORTH IT? CLEARLY, NEW DATA SAY," BY DAVID LEONHARDT, IN THE UPSHOT, *NEW YORK TIMES*. PUBLISHED ONLINE MAY 27, 2014 (*pay increase with college degree*)

Research links family income to variation in anatomy, especially in the cortex, which supports learning, thought and action.

ning in 2001, developmental psychologists Charles A. Nelson III of Harvard University, Nathan A. Fox of the University of Maryland and Charles H. Zeanah, Jr., of Tulane University compared kids who remained trapped in that system with those who escaped to foster care or adoption and found dire emotional and cognitive repercussions for the first group. They confirmed that the environment can shape cognitive and brain growth and showed that a supportive intervention can substantially ameliorate early privations.

Seeing the Difference

Most children growing up in poverty face some adversity, but it is rarely as extreme as the absence of human interaction and enrichment experienced by the Romanian orphans. Nevertheless, even lesser deprivation appears to alter brain development. In the past few years several large, high-quality studies using MRI have linked variation in a child's neuroanatomy with family income. In no area are the disparities more striking than in the cortex.

One of us (Gabrieli) has made this observation in his own laboratory at the Massachusetts Institute of Technology. He, Allyson Mackey and their colleagues compared cortical thickness among 58 eighth grade students from lower-income versus higher-income families. The results, published in 2015, revealed that the lower-income group had a thinner cortex in widespread regions of the brain. For all students, regardless of income, a thicker cortex was associated with better scores on statewide tests of reading and math. This study, therefore, directly related family income, brain anatomy and educational achievement.

In the same year, cognitive neuroscientist Kim Noble of Columbia University and her colleagues published findings from an MRI examination of 1,099 children ages three through 20. They discovered that cortical surface area was larger in children with greater family income. Critically, they found that small differences in income among families earning less than $50,000 a year were associated with relatively large differences in surface area. But this pattern did not hold true among kids from families who made more than $50,000. These findings suggest a threshold model in which small disparities in earnings may matter greatly among lower-income individuals, but above a certain income level, these differences have less impact.

Also in 2015 Seth Pollak, a psychologist at the University of Wisconsin–Madison, published a study of 389 children and young adults, aged four to 22, that examined the relation between household poverty, academic performance and MRI data. He and his colleagues found that people with higher scores on cognitive and achievement tests had greater cortical volumes in the frontal and temporal lobes—and, as in the other studies, poorer children had less cortical gray matter (a finding that in all three studies was unrelated to race or ethnicity).

All of this work is correlational, so it is important to note that it cannot prove whether or not an impoverished environment *caused* these changes—or, for that matter, whether these differences in structure definitely translate into academic deficits. There are some remarkable students, for example, who do very well in school despite an impoverished background, and we do not know how their neural structure compares. It may resemble that of a more affluent child—or perhaps their brain can compensate, enabling equal academic performance despite differences in brain architecture.

The consistent finding that poverty is associated with a smaller cortex is notable, however, because we associate brain maturation from childhood through young adulthood with a thinning cortex. In fact, several studies have reported that better cognitive abilities are associated with a thinner cortex among adolescents at a given age. (These findings most likely involved children from higher-income families who are more likely to volunteer for research studies.)

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On the one hand, a reduced cortex may simply reflect the deleterious consequence of impoverished environments. On the other hand, it could reflect a protective adaptation to such environments. Accelerated thinning could perhaps diminish the influence of negative experiences on the developing brain. Preventing the brain from being shaped by harsh influences over the course of many years could be an evolutionarily adaptive response, helping a child to better cope in adverse conditions—but premature thinning could also reduce education's influence on the developing brain.

A Question of Timing?

Researchers have been trying to determine when brain differences associated with SES first become apparent: Do they start in the womb or as an infant experiences more or less supportive environments after birth? In principle, brain imaging offers a novel way to answer these questions, but findings thus far have been inconsistent.

One 2015 study of 44 infants by cognitive neuroscientist Martha Farah of the University of Pennsylvania and her colleagues found that by one month of age, higher SES (defined by income and maternal education) was associated with larger cortical volume in girls. This finding suggests that differences emerge very early—although it is hard to know what such variation means.

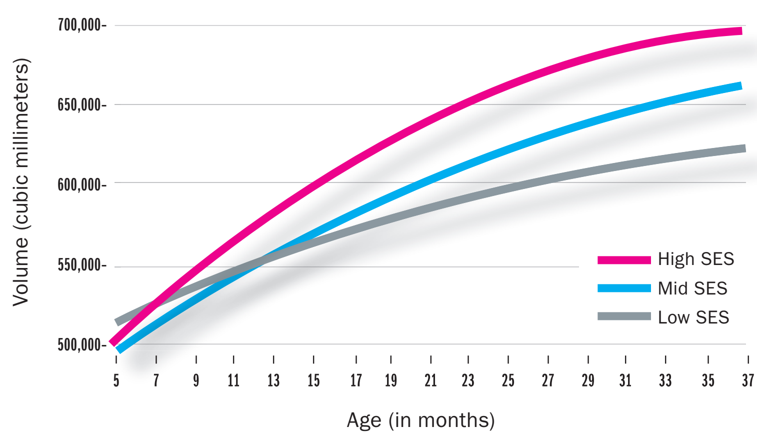
Pollak and his colleagues, however, looked at infants aged five months to four years and in 2013 found that SES-related brain differences were minimal at early ages but increased over time. This gap does not grow indefinitely, however. Investigation later in life has yielded no evidence for widening brain differences after early childhood.

It is also important to consider the specific influences that may shape development during these years. Another study by Farah linked home environment to brain development. Researchers visited homes when children were four and then again at eight years of age, and both times they measured environmental stimulation, such as exposure to books, conversation, trips and music.

When the same group of kids reached adolescence, they were given MRI scans. The researchers found that a stimulating home at age four, but not at age eight, predicted greater cortical thickness in the frontal and temporal cortex. It may be that the home environment has a particularly powerful influence on brain development in the early childhood years—or that by age eight, school and social peers exert greater influence than the home does.

It is also possible that, given the range of factors related to socioeconomic status, there may not be a single or simple answer to the question of when brain differences first emerge. Furthermore, there may not be a special or "critical" period of development that is uniquely potent in predicting long-term outcomes. It seems logical that early preventive help is more likely to be effective than remedial support after a child has fallen behind, but education occurs continuously through a child's development and matters at all ages.

Total Gray Matter



Using MRI to track brain development in 77 infants, psychologists at the University of Wisconsin–Madison found that differences associated with socioeconomic status (SES) became increasingly pronounced over time. By age three, toddlers from low-income households showed significantly less gray matter than those raised in wealthier homes.

SOURCE: "FAMILY POVERTY AFFECTS THE RATE OF HUMAN INFANT BRAIN GROWTH," BY JAMIE L. HANSON ET AL., IN *PLOS ONE*, VOL. 8, NO. 12, ARTICLE NO. E80954; DECEMBER 11, 2013

Finding Ways to Help

Early experience does not *determine* outcomes; it merely influences their probability. Given individual variation in response to adversity, we cannot and should not make assumptions about a child's potential based on his or her background. The brain, after all, is plastic and continues to change with experience over a life span.

Yet the longer we wait to get started, the more intensive the effort we may need to counteract the effects of early adversity. The detriments associated with the Romanian orphanages, for example, were not as pronounced among kids placed into family

A number of research-based programs for disadvantaged kids are showing good results. Structured group play sessions, such as those offered at Childhaven in Seattle (*left*) or a Tools of the Mind classroom such as this one at Christina Seix Academy in Trenton, N.J. (*right*), can help boost executive functions, a crucial set of skills that includes problem solving, reasoning and planning.

COURTESY OF CHILDHAVEN (*left*); COURTESY OF TOOLS OF THE MIND (*right*)

foster care early in childhood. The best solution is therefore prevention, and the next best is remediation. That means that tackling income inequality—and particularly extreme child poverty—at the societal level is of paramount importance, and we hope that neuroscientific evidence can be a spur for shifting policy in that direction. Meanwhile there are some promising steps, inspired by the new findings, that we can take to mitigate the negative effects of indigence on children.

There are a number of ways people are trying to improve life outcomes for disadvantaged children—including efforts targeting factors such as sleep and nutrition, cognitive and academic skills, and even finance, career development and parenting strategies for parents and caregivers. Columbia's Noble and her colleagues, for example, have begun a pilot project in which they are testing whether cash transfers to low-income mothers will improve their child's environment and cognition and lower maternal stress. If the threshold model is correct, even modest financial assistance could make a big difference.

Applying techniques from neuroscience may yield unique insight into a given intervention's power. One example of an approach that has been assessed in part through brain measurements is the Kids in Transition to School (KITS) program, developed by psychologist Philip Fisher and his colleagues at the Oregon Social Learning Center, which works with children in foster care and youngsters from low-income families two months before the start of kindergarten and continues until two months after entry.

Aimed at boosting self-regulatory skills, as well as early literacy and prosocial behavior, KITS includes 24 sessions of therapeutic play for children, as well as an eight-session workshop for caregivers. In the classroom, students practice skills such as sitting still and raising their hand, as well as cooperating with their peers. In the workshop, adults learn ways to establish routines with children and encourage good behavior.

Two-generation approaches are effective for many reasons, among them the fact that when parents are involved, children can be helped outside of class and they may not feel as singled out among their peers. In a paper published in 2013 Helen Neville, a cognitive neuroscientist at the University of Oregon, and her colleagues compared a parent-and-child intervention based on KITS with an intervention focused solely on kids. They found that the combined approach did a better job of boosting nonverbal IQ and language skills. This result was supported by electroencephalography (EEG) findings indicating that the children had a bigger improvement in their brain's capacity to filter out distracting information while focusing on a task.

Both of us are directly involved in testing other interventions for children in poverty that involve their parents and caregivers. As part of the Boston Charter Research Collaborative, Gabrieli works with teachers at six charter school management organizations, serving nearly 7,000 inner-city students in the metropolitan area. The teachers describe their challenges, and researchers at Harvard and M.I.T. offer evidence-based solutions; together they implement and evaluate these programs. Some of the participating students come for brain imaging before and after an intervention so that beneficial brain plasticity can be visualized.

Neuroimaging can also pinpoint cognitive targets for an intervention. The executive functions, for example, are a suite of skills that help people focus on a task, regulate feelings and behaviors, and consider possible consequences before making a decision. They not only increase the odds of staying in school but also appear to be highly vulnerable to poverty. Indeed, executive functions are associated with the prefrontal cortex, an area that shows clear differences in imaging studies that compare children of wealth with those of poverty.

Early findings suggest certain classroom activities can boost cognitive functions vulnerable to poverty within 10 weeks.

Bunge is involved in the Frontiers of Innovation (FOI) network, established by the Center on the Developing Child at Harvard. This group of researchers and practitioners at multiple sites around the U.S. identifies and develops promising approaches for assisting parents and other caregivers of young children living in adversity. Through FOI, Bunge's team at U.C. Berkeley has been collaborating with Seattle-based Childhaven, which provides therapeutic services to children under age six who have suffered neglect or maltreatment at home. Pilot data from this work suggest that simple classroom activities, such as structured group play that requires children to follow explicit rules and take turns with their classmates, can begin to boost executive functions within 10 weeks.

Several other approaches have shown success in strengthening these functions. One example is the Tools of the Mind curriculum, an alternative to traditional kindergarten developed at Metropolitan State University of Denver by psychologists Elena Bodrova and Debora Leong. The curriculum focuses on building executive functions through "scaffolded" play, which involves targeted interactions with peers and teachers. In 2014 psychologists Clancy Blair and Cybele Raver of New York University found this program was especially beneficial in high-poverty preschools.

What Comes Next?

Although the nature of brain differences was unknown until the past decade, it had to be expected that the profound disparities in educational, occupational and health outcomes associated with childhood poverty or affluence would be reflected in the brain's development. In many ways, the findings complement the long-standing research into the income-achievement gap.

Yet this work also hints at a special role for neuroscience, beyond descriptive imaging. Monitoring the progress of a particular approach with EEG, as well as behavioral measures, for instance, can offer a fast and revealing indicator of its strengths or failings. Furthermore, the nature of neural differences associated with SES is instructive. If longitudinal evidence supports the idea that more rapid cortical thinning occurs in children raised in poverty, then developing strategies to slow such thinning could be helpful.

Ultimately individual children will respond in varied ways to any given intervention. The challenge is to develop personalized solutions that are not overly expensive or time-consuming for educators. Broadly speaking, the most beneficial programs will be intensive (involving multiple, regular sessions or spanning several years), engage a range of skills in diverse ways, and incorporate not only children and educators but also caregivers and the home environment. Best of all would be public policies and societal changes that take aim at child poverty and income inequality.

Children from disadvantaged backgrounds face many challenges, but thanks in part to the remarkable power of neuroplasticity, no one's story is predetermined. Our hope is that the new brain-based findings may inspire and guide solutions to help these kids flourish and thrive. M

MORE TO EXPLORE

- **Neuroanatomical Correlates of the Income-Achievement Gap.** Allyson P. Mackey et al. in *Psychological Science,* Vol. 26, No. 6, pages 925–933; June 2015.
- **Money, Race and Success: How Your School District Compares.** Motoko Rich, Amanda Cox and Matthew Bloch in *New York Times;* April 29, 2016. **www.nytimes.com/interactive/2016/04/29/upshot/money-race-and-success-how-your-school-district-compares.html**
- Center on the Developing Child, Harvard University: **http://developingchild.harvard.edu**

From Our Archives

- **Anguish of the Abandoned Child.** Charles A. Nelson III, Nathan A. Fox and Charles H. Zeanah, Jr.; *Scientific American,* April 2013.